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ARMY PRELIMINARY EVALUATION III AND IV YCH-47C MEDIUM TRANSPORT HELICOPTER

FINAL REPORT

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OCTOBER 1970

US ARMY AVIATION SYSTEMS TEST ACTIVITY

EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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EDWARDS AIR FORCE BASE, CALIFORNIA

ABSTRACT

Army Preliminary Evaluation (APE) III and IV of the CH-47C helicopter was conducted in the vicinity of Philadelphia, Pennsylvania. APE III consisted of vibration noise level tests and a re-evaluation of the stability and control characteristics modified by the incorporation of engineering changes to correct the handling qualities deficiencies found during APE II. APE IV was a re-evaluation of the vibration characteristics which was required because of structural modifications incorporated in the aircraft following APE III. The helicopter showed significant improvements in trimmability, static and dynamic longitudinal stability and lateral-directional stability as compared to aircraft flown during APE I and II. The longitudinal stability improvements permitted sustained "hands off" flight. The vibration levels experienced during APE IV were improved over APE III. The aircraft met all requirements except two of the detail specification and two of the military specification. No deficiencies were detected; however, correction of 16 shortcomings is desirable for improved helicopter operation. The primary shortcomings detected during these tests are uncommanded pitch attitude changes while re-trimming in the pitch stability augmentation (PSA) system ON/detent OFF mode and high noise levels in the cockpit and cabin areas. Other shortcomings are: unstable and neutral longitudinal trim position gradients, uncommanded pitch attitude changes following failure of the PSA system airspeed and attitude feedback signals, blade "bang" (rotor blade noise) phenomenon, uncommanded auxiliary power unit shutdown and inaccurate fuel quantity indications. The high, thrust control rod sensitivity, pitch-to-thrust aerodynamic coupling and basic stability augmentation system static and dynamic longitudinal instability shortcomings reported in APE II are still present.

FOREWORD

During the Army preliminary evaluation, the CH-47C test helicopters with special instrumentation installed were maintained by the Boeing Company, Vertol Division which also provided data reduction support and office facilities. The US Naval Plant Representative, Boeing Company, Vertol Division provided copilot support for vibration acceptance criteria flights in production helicopters.

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INTRODUCTION

BACKGROUND

1. The hot day, high-altitude performance degradation of the CH-47 helicopter in Vietnam has emphasized the importance of improving the helicopter's payload and speed capabilities. Based on the requirement for an increased payload capability, a CH-47 Product Improvement Program evolved (ref 1, app I). This improvement program outlines a two-step program to incorporate performance, stability and vibration level improvements in production CH-47 helicopters. The helicopter configured for step-one modification incorporating uprated engines and redesigned rotor blades has been designated the CH-47B. The second step in the program provides for the incorporation of a higher powered engine to obtain a further increase in payload lift capability. The helicopter configured for step-two modification has been designated the CH-47C.

2. Authority for the US Army Aviation Systems Test Activity (USAASTA) participation in the CH-47 Product Improvement Program test was provided by the test directive issued by the US Army Test and Evaluation Command (USATECOM) on 17 June 1966 (ref 2, app I). The test plan (ref 3) for the Army Preliminary Evaluation (APE) was changed from a single phase to a three-phase evaluation: APE I (performance guarantee compliance), APE II (stability and control and limited performance tests) and APE III (vibration and noise-level compliance). These changes were approved by the CH-47 Project Manager and by the US Army Aviation Systems Command (USAAVSCOM) in February 1968. APE IV was directed by USAAVSCOM (ref 4) for the purpose of evaluating the airframe and systems modifications which were required by the failure of the helicopter to meet the vibration requirements of the detail specification (ref 5) during APE III. All tests were conducted in the vicinity of Philadelphia, Pennsylvania.

3. The APE I testing was completed on 14 March 1968, and the final report was distributed in November 1968 (ref 6, app I). All performance guarantees as specified in the detail specification (ref 5) for the model CH-47C helicopter were met during APE I.

4. APE II was completed on 2 July 1968, and the final report was forwarded for distribution in July 1969 (ref 7, app I). Several deficiencies and shortcomings were detected during APE II. The most serious deficiencies were the unacceptable static and dynamic longitudinal stability characteristics. Because of these deficiencies, the APE III test plan (ref 3) was expanded to include an evaluation of the proposed contractor modifications incorporated on the test helicopter.

TEST OBJECTIVES

5. The purpose of APE III and IV was to furnish the CH-47 Project Manager and USAAVSCOM (the procuring activity) with preliminary and timely results derived from the US Army tests of the YCH-47C helicopter during the contractor's development program. Specific objectives were as follows.

a. To provide quantitative/qualitative engineering flight test data.

b. To evaluate the aircraft's suitability for its intended mission.

c. To assist in determining the flight envelope for flight operations.

d. To detect deficiencies and evaluate changes incorporated to correct previous deficiencies.

DESCRIPTION

6. The helicopters flown for vibration and noise level compliance and acceptance document data during APE III were: S/N 66-19121 (production tab number[1] B-379) for the stability and control evaluation and S/N 66-15812 (production tab number B-524). The test helicopter flown for vibration compliance and acceptance document data during APE IV was S/N 68-15868 (production tab number B-570). The test helicopters were in the external configuration specified in the detail specification less the cargo mirrors. Nonstandard items mounted externally on helicopter B-379 were: slip ring assemblies on both rotor heads, Rosemont temperature probes on the underside of the fuselage and a pitot-static boom on the nose. Significant design changes from the CH-47B applicable to the test helicopters are noted in reference 7, appendix I. Additional changes incorporated on the test helicopters are shown in appendix IV. The test helicopters are shown in photographs 1, 2, 3 and 4, appendix VI.

7. Helicopter B-379 was used for the stability and control tests and was powered by two prototype YT55-L-11 calibrated engines (maximum power of 3750 shaft horsepower (shp)) in lieu of production T55-L-11 engines. Design gross weight (grwt) was 33,000 pounds,

[1]Production tab numbers are used throughout this report to refer to a helicopter used for a specific test.

and the alternate design grwt was 46,000 pounds. Physical characteristics of the CH-47C are presented in appendix V. Cockpit instrumentation was nonstandard, and helicopter loading was nonrepresentative because of the ballast and instrumentation requirements.

8. Helicopter B-524 was used for vibration and noise level tests and was powered by two T55-L-7C engines (maximum power of 2850 shp) in lieu of production T55-L-11 engines. Design grwt was 33,000 pounds, and alternate design grwt was 40,000 pounds. Cockpit instrumentation was nonstandard and helicopter loading was as specified in reference 5, appendix I.

SCOPE OF TEST

9. Helicopters B-379, B-524 and B-570 were evaluated with respect to the mission as a transport helicopter as defined in the detail specification (ref 5, app I). During APE III, 20 flights were conducted for a total 32.3 hours of flight time (seven flights and 11.3 hours were productive). Handling qualities were evaluated under selected loading conditions and power settings against the requirements of the military specification (ref 8) or against deviations from the military specification contained in the detail specification (ref 5). Vibration and noise levels were evaluated on the ground and in flight under the loading conditions and power settings specified in the detail specification. Vibration levels were also evaluated at the empty weight plus full fuel condition. Noise levels were conducted concurrently with the vibration tests. During APE IV, five flights were conducted for a total 7.8 hours of flight time (6.5 hours were productive).

METHOD OF TEST

10. Standard US Navy test methods (ref 14, app I) were used to acquire stability and control data for analysis and evaluation for the determination of military and detail specification compliance. A pilot rating scale (PRS) (app IX) was used to augment the pilot's qualitative flying qualities comments. Vibration and noise-level tests were conducted in accordance with procedures contained in the detail specification.

11. A detailed list of the test instrumentation is contained in appendix III. Photographs 5 through 16, appendix VI, show the cockpit and cabin instrumentation as installed on the test helicopters.

CHRONOLOGY

12. The chronology for APE III is as follows.

Test directive received	1	June	1966
Test aircraft received:			
Stability and control test aircraft	19	September	1968
Vibration and noise level test aircraft	10	December	1968
Test started	19	September	1968
Test completed	10	January	1969
APE debriefing	20	January (interim)	1969
Advance copy of final report submitted	9	October	1969

13. The chronology for APE IV is as follows.

Test directive received	31	January	1969
Test aircraft received	24	March	1969
Test started	24	March	1969
Test completed	27	March	1969
APE debriefing	1	April	1969
Advance copy of final report submitted	9	October	1969

RESULTS AND DISCUSSION

STABILITY AND CONTROL

General

14. The purpose of incorporating the Engineering Change Proposals (ECP) 598, 610, 611R1 and 620 was to correct handling qualities shortcomings identified during APE II. The most significant change in the flight control system was the incorporation of a two-mode (NORMAL and AUTO) Pitch Stability Augmentation (PSA) system (ECP 611R1) for the purpose of correcting the longitudinal dynamic instability reported in APE II (ref 7, app I). The PSA system enhanced the longitudinal handling qualities to the degree that in either mode, sustained hands-off stabilized climbing, descending and level flight were possible. The PSA system was able to provide a relatively constant airspeed hold at all speeds between approximately 60 KCAS to 150 KCAS with variation of $\pm\frac{1}{2}$ knot in smooth air increasing to ± 8 knots in moderate turbulence. Altitude control was easily accomplished with small adjustments of the thrust control rod. Aircraft heading could be held constant with occasional small lateral cyclic control inputs. Two undesirable features of the PSA system increased the piloting task during the tests. Operation in the PSA system normal (detent OFF) permitted uncommanded pitch attitude changes to occur whenever the longitudinal cyclic was displaced from trim before activating the centering release device (trim button). The magnitude of the pitch attitude change increased with increased longitudinal cyclic displacement from trim. Selection of the PSA system AUTO (detent ON) mode eliminated the uncommanded pitch attitude change problem associated with retrimming in the manner described above. However, when the pilot commanded pitch attitude changes to vary airspeed or to assist the PSA system in holding airspeed in turbulent air, the PSA system was automatically deactivated. The pilot was then flying a basic SAS-augmented aircraft until the cyclic was returned to a trim (zero longitudinal force) position. It is recommended that the PSA system be improved to provide "full-time" pitch stability augmentation and eliminate the shortcomings of the two-mode PSA system.

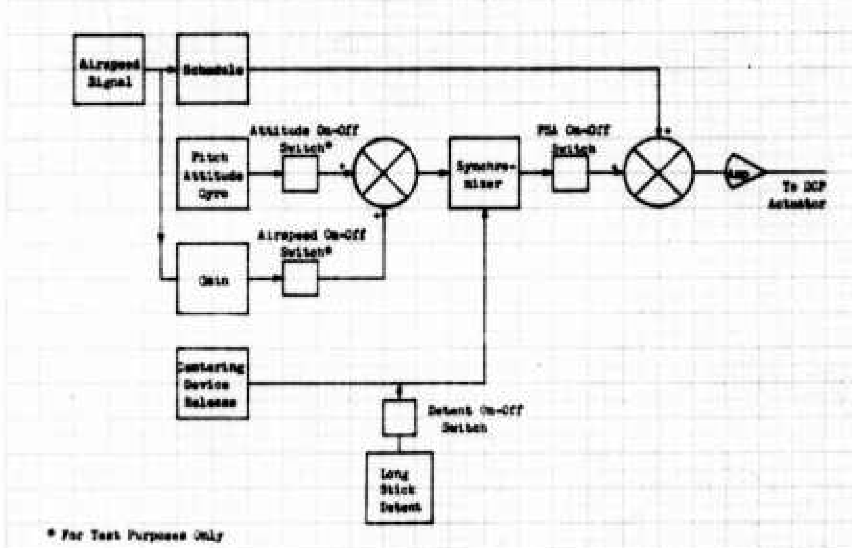
Flight Control System

15. The flight control system of the CH-47C used for stability and control testing was the same as that reported in reference 6, appendix I, except for the incorporation of ECP 598, revision of the forward rotor longitudinal cyclic speed trim (LCST) schedule; ECP 610, addition of balance springs to collective and differential control systems; ECP 611R1, improvement of longitudinal stability, and ECP 620, improvement of roll axis controllability.

16. Programming of the forward-head swashplate was revised to alleviate forward-head droop-stop contact during maneuvering flight above the 10,000-foot pressure altitude (Hp) at 235 rpm rotor speed. Figure 1, appendix II, shows the difference in programming between the APE II and III LCST schedules (ECP 598). The full retracted forward head swashplate tilt was changed from 1.5 degree aft to 0.5 degree aft. In addition, a forward cyclic pressure bias of 0.15 degree per thousand feet was incorporated. The aft head swashplate program is unchanged. Figure 2 shows that for all flight conditions tested the LCST schedule was programming within the ±15-knot tolerance band established by the contractor. Within the scope of the tests, no droop stop contact was experienced. ECP 598 is satisfactory for Army use.

17. The basic differential collective pitch speed trim (DCPST) schedule was incorporated to provide positive longitudinal control position stability with airspeed by programming aft differential collective pitch (DCP) with increasing airspeed and forward DCP with decreasing airspeed. Figure 3, appendix II, shows a comparison of the basic DCPST schedules flown in APE II with APE III and IV. The schedule resulted in stable pitching moments when the airspeed was disturbed from the trim condition. The APE III and IV schedules provided less stable pitching moments than the APE II schedule. The schedule revision was due to the incorporation of ECP 611R1. An explanation of ECP 611R1 is contained in paragraph 18. Figure 3 shows that for the flight conditions tested the DCPST was programming satisfactorily.

FIGURE 1.
SCHEMATIC OF PITCH STABILITY
AUGMENTATION SYSTEM



18. The PSA system was designed to deactivate whenever the centering device release (trim button) was depressed. Figure 1 on page 6 shows a schematic of the PSA system provided by ECP 611R1. The test helicopter (B-379) was equipped with a three position (OFF/NORMAL/AUTO) PSA system mode switch. The OFF mode provided basic SAS characteristics. The NORMAL mode (detent OFF) provided continuous signal equivalent to 0.13 inch of longitudinal cyclic per degree of pitch attitude change and 0.07 inch of longitudinal cyclic per knot of airspeed change about trim, to the DCPST, regardless of the cyclic control position. Uncommanded pitch changes occurred when the flight control centering device release button was depressed after a new pitch attitude (airspeed) was achieved. The uncommanded pitch change was caused by the DCPST returning to its basic schedule. The maximum uncommanded DCPST input was equivalent to a slow 2½-inch cyclic control movement. The pilot was then required to "hunt" for the new cyclic trim position to hold the desired airspeed (PRS A4). Large uncommanded pitch attitude changes and "hunting" for cyclic trim positions were eliminated by depressing the centering release button before changing attitude. In the AUTO mode (detent ON), the PSA system operated in the same manner as with the detent OFF, providing the cyclic control was not moved more than 1/8-inch forward or aft of its trim position. Motion beyond these limits caused automatic deactivation of the PSA system. The longitudinal static and dynamic stability was then provided only by the stability augmentation system (SAS). The SAS-only stability characteristics are discussed in paragraphs 28 and 37 and were similar to those reported in APE II (ref 7, app I). Detent ON retrimming produced no large uncommanded pitch changes since the DCPST was constantly being reset to its normal position whenever the cyclic was moved beyond the ±1/8-inch limit. The helicopter's static and dynamic characteristics resulting from the detent ON or OFF operation are discussed in paragraphs 29, 30, 36 and 38.

Control Force Characteristics

19. Control force measurements were not taken during these tests. Control force characteristics are presented in reference 6, appendix I.

Trimmability

20. Within the scope of these tests, the longitudinal, lateral and directional control forces were easily trimmed to zero using the control centering switch as reported in reference 6, appendix I.

21. The directional pedal unbalance condition reported in APE II (ref 7, app I) was corrected by the incorporation of balance springs (ECP 610). Coordinated flight was easily maintained with the control centering released. The directional pedal control balance was significantly improved over that reported in APE II and is satisfactory for Army use (PRS A2).

22. The longitudinal and lateral trim changes with rate of climb (R/C) and descent were qualitatively evaluated as satisfactory (PRS A3) and similar to that reported in APE I (ref 6, app I).

Control Trim Position

23. Control trim position characteristics were investigated by trimming the helicopter in steady heading, zero-sideslip level flight. Airspeed was increased in approximately 20-knot increments by adjusting the collective pitch to maintain altitude. Data were recorded for each stabilized condition. Figures 4 and 5, appendix II, present the control position trim data curves recorded during the tests. The contribution of the DCPST in providing longitudinal control trim position is shown as the difference between the longitudinal stick position DCPST OFF and DCPST ON. The DCPST OFF data represents the control trim positions which would exist if the DCPST was disconnected prior to takeoff.

24. Longitudinal control trim positions were evaluated in level flight from approximately 45 knots calibrated airspeed (KCAS) to maximum level-flight airspeed (V_H). The data show that the longitudinal trim position gradients were stable to 50 KCAS and then became neutral to unstable with airspeed increasing to V_H. Pilot effort was high for level-flight airspeed changes in the unstable areas because the new trim position was not normal for the airspeed change. This characteristic increases the piloting task during marginal visual flight rules (VFR) and instrument flight rules (IFR) (PRS A4). Correction of the unstable longitudinal trim position gradient is desirable for improved helicopter operation.

25. The lateral control trim position data show that less than 0.8-inch right lateral cyclic was required as airspeed was increased from minimum power speed (V_{min}) to V_H. The directional control trim position data show that virtually no directional pedal inputs were required as airspeed was increased from V_{min} to V_H. The small lateral and directional control trim changes required with airspeed minimize pilot effort when retrimming in level flight and are satisfactory for Army use (PRS A2).

26. Within the scope of the tests, the longitudinal, directional and lateral control trim position gradients were not adversely affected by altitude for similar gross weights. Longitudinal and lateral control trim positions shifted with gross weight and cg but did not affect the flying qualities of the helicopter.

Static Longitudinal Stability

27. Static longitudinal stability characteristics were investigated by trimming the helicopter in steady heading level flight. Airspeed was increased and decreased in approximately 5-knot increments about the trim airspeed with collective fixed, and data were recorded for each stabilized condition. Figures 6 through 18, appendix II, present typical PSA system ON static longitudinal collective-fixed stability characteristics and test conditions. A summary of all conditions tested is presented in table 1. The DCPST contribution to the longitudinal control gradient is shown as the difference between the DCPST OFF (longitudinal stick position) and DCPST ON (longitudinal stick position).

Table 1. Static Longitudinal Collective-Fixed Stability in Level Flight.

Average Gross Weight (lb)	Trim Airspeed (KCAS)	Rotor Speed (rpm)	Average Density Altitude (ft)	Average CG (in.)	Detent[1] System	Stability Characteristics
34,400	147(V_{NE})[2]	236	4,280	7.8 aft	ON	Positive above and below trim airspeed
33,930	125(V_{cruise})[3]	236	4,470	8.1 aft	ON	Neutral above and negative below trim airspeed
33,400	77(V_{min})	236	4,340	8.4 aft	ON	Neutral above and below trim airspeed
37,380	75(V_{NE})	246	13,910	6.2 aft	ON	Negative above and neutral below trim airspeed
36,140	61(V_{NE}-15)	246	13,710	6.9 aft	ON	Neutral to positive above and negative below trim airspeed
43,650	132(V_{NE})	246	4,060	5.0 aft	ON	Neutral above and below trim airspeed
43,180	85(V_{cruise})	246	3,540	5.2 aft	ON	Slightly positive above and below trim airspeed
42,400	59	246	3,020	5.4 aft	ON	Negative above and below trim airspeed

See footnotes at end of table 1

Table 1. (continued)

Average Gross Weight (lb)	Trim Airspeed (KCAS)	Rotor Speed (rpm)	Average Density Altitude (ft)	Average CG (in.)	Detent System	Stability Characteristics
46,360	72(V_{NE})	247	7,700	3.5 aft	ON	Slightly positive above and neutral below trim airspeed
36,020	144(V_{NE})	237	5,000	7.0 aft	OFF	Positive above and below trim airspeed
35,540	127(V_{cruise})	237	5,100	7.2 aft	OFF	Positive above and below trim airspeed
32,330	73(V_{min})	235	4,700	8.7 aft	OFF	Positive above and below trim airspeed
36,590	98(V_{NE})	236	10,300	6.5 aft	OFF	Positive above and below trim airspeed
36,350	72(V_{min})	236	10,400	6.7 aft	OFF	Positive above and positive to neutral below trim airspeed
37,260	71(V_{NE})	246	13,450	6.2 aft	OFF	Positive above and positive to neutral below trim airspeed
36,910	57(V_{NE}-15)	246	13,400	6.4 aft	OFF	Positive above and neutral to negative below trim airspeed
43,165	132(V_{NE})	247	5,000	4.8 aft	OFF	Positive above and below trim airspeed

Table 1. (continued)

Average Gross Weight (lb)	Trim Airspeed (KCAS)	Rotor Speed (rpm)	Average Density Altitude (ft)	Average CG (in.)	Detent System	Stability Characteristics
42,630	85(V_{min})	246	3,780	5.2 aft	OFF	Positive above and positive to neutral below trim airspeed
41,910	57	248	3,970	5.9 aft	OFF	Positive above and neutral to negative below trim airspeed
41,460	142(V_{NE})	247	2,200	5.9 aft	OFF	Positive above and positive to neutral below trim airspeed
45,770	76(V_{NE})	247	7,900	3.8 aft	OFF	Positive above and below trim airspeed
32,570	153(V_{NE})	236	-100	1.0 aft	OFF	Positive above and below trim airspeed
31,980	152(V_{NE})	237	-60	0.7 aft	ON	Neutral to negative above and positive below trim airspeed
29,220	136(V_{NE})	236	9,940	1.9 aft	OFF	Positive above and neutral below trim airspeed
29,490	136(V_{NE})	237	10,000	1.7 aft	ON	Neutral above and below trim airspeed
28,260	104(V_{cruise})	238	9,650	2.5 aft	OFF	Positive above and below trim airspeed

Table 1. (continued)

Average Gross Weight (lb)	Trim Airspeed (KCAS)	Rotor Speed (rpm)	Average Density Altitude (ft)	Average CG (in.)	Detent System	Stability Characteristics
28,500	104(V_{cruise})	238	9,520	2.4 aft	ON	Neutral above and below trim airspeed
27,790	59(V_{min})	238	8,820	2.8 aft	OFF	Positive above and positive to neutral below trim airspeed
27,940	59(V_{min})	238	9,160	2.7 aft	ON	Neutral above and neutral to negative below trim airspeed

[1]PSA system ON.
[2]Never exceed airspeed.
[3]Cruise speed.

28. Static longitudinal stability characteristics were qualitatively evaluated with the PSA system OFF and were similar to those reported in APE II (ref 7, app I). The aircraft failed to meet the requirements of deviations 5 and 11 of the detail specification for IFR and VFR conditions; in that, qualitatively, the characteristics became increasingly unsatisfactory for VFR (PRS A4) and IFR operations (PRS A6) as gross weight and altitude increased and cg moved aft.

29. Collective-fixed static longitudinal stability characteristics with the PSA system ON and detent ON are presented in figures 6 through 9. The figures show that the collective-fixed static longitudinal stability was neutral or slightly negative in most cases. However, if the cyclic was not moved from trim, the attitude and airspeed reference signals supplied to the DCPST actuator by the PSA system provided positive static stability for a given trim airspeed for external pitch attitude or airspeed perturbations. If the pilot was required to make cyclic inputs to control the helicopter, such as to compensate for large gust upsets, maneuvers or to change airspeed, the PSA system was deactivated by a detent switch. The helicopter was then influenced by the basic SAS and DCPST inputs. In this configuration the static longitudinal stability characteristics are unsatisfactory. Moderate pilot effort was required to control the helicopter. Correction of the PSA system ON/detent ON static longitudinal instability when the cyclic stick is displaced is desirable for improved helicopter operation (PRS A4).

30. Collective-fixed static longitudinal stability characteristics with the PSA system ON/detent OFF are shown in figures 10 through 14, appendix II. Figures 15 through 18 show a comparison of the PSA system ON and the detent ON/OFF conditions. For most conditions tested, the static longitudinal stability with detent OFF was strongly positive and significantly improved over that reported in APE II. The gradient below trim airspeed tended to become neutral to slightly negative at low airspeeds (40 to 60 KCAS) and was slightly degraded by increasing gross weight and/or altitude. After making airspeed changes of more than 5 knots from trim, detent OFF retrimming resulted in objectionable longitudinal pitching moments. Pitching moments equivalent to approximately 2.5 inches of stick travel were experienced when airspeed was changed more than 30 knots before depressing the control centering device release button. Continual retrimming was required when accelerating or decelerating and resulted in moderate pilot effort particularly during takeoff and landing maneuvers. Correction of the PSA system ON/detent OFF retrimming characteristics is desirable for improved helicopter operation (PRS A4). It is recommended that the following note be placed in the operator's manual: "When operating the PSA system ON/detent OFF, depress the control centering device release button

prior to initiating an airspeed and/or attitude change and release the button only after stabilization at the new flight condition".

Static Lateral-Directional Stability

31. Static lateral-directional stability characteristics were re-investigated at various airspeeds, gross weights and altitudes by trimming the helicopter for steady heading, zero-sideslip level flight. Sideslip was increased in 5-degree increments while maintaining a collective-fixed, steady course.

32. The level flight, lateral-directional stability characteristics are presented in figures 19 and 20, appendix II. A comparison between the static lateral-directional stability characteristics exhibited in APE II and III is presented in figure 21. The characteristics determined in APE III were similar to those reported during APE II (ref 7, app I). The incorporation of ECP 620 (improvement of roll axis controllability) did not degrade the static lateral-directional stability of the helicopter. The incorporation of ECP 611R1 (improvement of longitudinal stability) did significantly improve the longitudinal stick gradient, in that for similar conditions of flight, 0.25 inch of aft longitudinal stick per 10 degrees of sideslip were required as compared to 1.5 inches of aft longitudinal stick per 10 degrees in APE II (PRS A2). The forward-head droop-stop pounding which occurred at high sideslip angles during APE II was not experienced during this evaluation. The static lateral-directional stability characteristics are satisfactory for Army use.

Controllability

33. The controllability was measured about the pitch and roll axes in forward flight and is defined by the control sensitivity (angular acceleration), control effectiveness (angular rate) and control power (attitude in a specified time). Figures 22 through 25, appendix II, show longitudinal and lateral controllability. Step inputs from 0.3 to 1.4 inch were made as discussed in references 7 and 14, appendix I.

34. The longitudinal controllability characteristics of the helicopter were similar to those reported in the APE II report. The lateral controllability characteristics were modified as a result of the incorporation of ECP 620 (improved roll axis controllability). For small lateral control inputs of 0.2 inches or less, the maximum angular accelerations were essentially the same as that reported in

the APE II report; however, the time to attain this maximum was more than doubled. This results in reduced control sensitivity. For lateral control inputs greater than 0.2 inches, the maximum angular acceleration was somewhat greater with ECP 620 incorporated, but with the increase in time to attain the maximum acceleration, the net effect resulted in a reduction in lateral control sensitivity. The longitudinal and lateral controllability characteristics met the requirements of the military specification and are satisfactory for Army use (PRS A3).

Dynamic Stability

35. Longitudinal dynamic stability characteristics were investigated in steady heading, zero-sideslip level flight. One-half second pulses, equivalent to an approximate 1-inch aft longitudinal cyclic control movement, were made using a SAS pulser-box input operating through the number one SAS pitch channel, to excite the short- and long-term helicopter response to gust upsets. The SAS inputs were 100 percent of the extendable link authority for the longitudinal axis. Long-term dynamic stability characteristics were also investigated by gradually reducing airspeed by 5 or 10 knots from trim and then replacing the cyclic in its trim position. Representative time histories of short- and long-term longitudinal dynamic stability characteristics are presented in figures 26 through 35, appendix II.

Table 2. Dynamic Stability Summary.

Gross Weight (lb)	Rotor Speed (rpm)	Density Altitude (ft)	Bias (kt)	Method of Excitation	Results
30,000	235	SL	145	Aft pulse	Damped
			148	10-knot decrease	Damped
			115	Aft pulse	Damped
			115	10-knot decrease	Damped
			64	Aft pulse	Damped
			66	10-knot decrease	Damped
		10,000	128	Aft pulse	Damped
			98	Aft pulse	Damped
			54	Aft pulse	Damped
37,000	245	13,800	58	Aft pulse	Damped
			58	Fwd pulse	Damped
			59	10-knot decrease	Damped
			48	Aft pulse	Neutrally Damped
			48	10-knot decrease	Neutrally Damped
			50	5-knot decrease	Neutrally Damped
	235	10,000	107	Aft pulse	Damped
			107	10-knot decrease	Damped

Table 2. (continued)

Gross Weight (lb)	Rotor Speed (rpm)	Density Altitude (ft)	Bias (kt)	Method of Excitation	Results
37,000	235	10,000	107	10-knot decrease	Neutrally Damped
		5,000	136	Aft pulse	Damped
			135	10-knot decrease	Damped
			115	Aft pulse	Damped
			115	10-knot decrease	Damped
			115	Aft pulse, single SAS	Damped
			115	10-knot decrease, single SAS	Damped
			61	Aft pulse	Damped
			61	10-knot decrease	Damped
		SL	140	Aft pulse	Damped
			142	Fwd pulse	Damped
			136	5-knot decrease	Damped
			140	5-knot increase	Damped
46,000	245	2 to 7000	70	MP climb, aft pulse	Damped
			70	MP climb, 10-knot decrease	Damped

Table 2. (continued)

Gross Weight (lb)	Rotor Speed (rpm)	Density Altitude (ft)	Bias (kt)	Method of Excitation	Results
46,000	245	2 to 7000	69	MP climb, aft pulse, SAS only	Divergent
		8,000	60	Aft pulse	Damped
			60	Lat pulse	Deadbeat
			60	Dir pulse	Deadbeat
			60	10-knot decrease	Damped
			60	Aft pulse, SAS only	Divergent
			47	Aft pulse	Damped
			47	Fwd pulse	Damped
			49	10-knot decrease	Damped
			45	Aft pulse, SAS only	Divergent
		4,000	119	Aft pulse	Damped
			119	10-knot decrease	Damped
			118	Aft pulse, SAS only	Divergent
			75	Aft pulse	Damped
			75	10-knot decrease	Damped
			75	Lat pulse	Deadbeat
			75	Aft pulse, SAS only	Divergent

Table 2. (continued)

Gross Weight (lb)	Rotor Speed (rpm)	Density Altitude (ft)	Bias (kt)	Method of Excitation	Results
46,000	245	4,000	48	Aft pulse	Damped
			47	10-knot decrease	Neutrally Damped
			48	Lat pulse	Deadbeat
			48	Aft pulse, SAS only	Divergent

36. Longitudinal dynamic stability response for the conditions tested are summarized in table 2. Figures 26 and 27, appendix II, show that for aft pulses the SAS provided a pitch attitude short-term response that was essentially deadbeat; small overshoot was noticed for trim airspeeds above 125 KCAS. The residual pitch rate and acceleration responses following a pulse input were significantly reduced from those of APE II, and the pitch attitude response was not apparent to the pilot. The PSA system provides a long-term pitch attitude response that is aperiodic to trim within 15 seconds. Figure 31 illustrates the significant improvement of helicopter response to aft pulses (PSA system ON) in APE III as compared to APE II. Within the scope of these tests, the dynamic stability characteristics (PSA system ON) in level flight following pulse inputs met the requirements of paragraphs 3.2.11 and 3.6.1.2 of the military specification and are satisfactory for Army use (PRS A3).

37. The helicopter response to aft pulses with the PSA system OFF (SAS ON only) was improved over that of APE II as a result of reshaping of the SAS gain (ECP 611R1), but this response was still divergent as shown in figures 33 and 34, appendix II. A comparison of aft pulse response data recorded during APE II and III (PSA system OFF) is shown in figure 35. The dynamic longitudinal stability characteristics of the CH-47C provided by the basic SAS failed to meet the requirements of paragraphs 3.2.11 and 3.6.1.2 of the military specification and are unsatisfactory for VFR (PRS A5) and IFR operations (PRS A6). Correction of the basic SAS dynamic longitudinal stability characteristics is desirable for improved helicopter operation.

38. The effect of failure of either feedback signal to the PSA system was investigated in stabilized level flight. Figures 36 and 37 show the helicopter response to an airspeed feedback signal and an attitude feedback signal, respectively. Failure of the airspeed

signal to reach the PSA system resulted in an uncommanded DCP re-synchronization which in turn caused an uncommanded divergent nose-down pitch attitude change. The pilot was forced to take over the controls to recover the aircraft (PRS A6). Failure of the attitude feedback signal resulted in a divergent pitch oscillation of the aircraft. The pilot had to take over the controls to reestablish trim airspeed (PRS A5). Operationally, a pilot would have no way of determining the cause of such uncommanded attitude changes. It is recommended that a "PSA system failure" caution light be incorporated to alert the pilot to these feedback system failures. Automatic deactivation of the PSA system is recommended if failure of either feedback signal occurs. Correction of the PSA system airspeed and attitude feedback signal failure characteristics is desirable for improved helicopter operation.

39. During level flight, military power (MP) climbs and minimum power descent testing, the ability of the PSA system to compensate for the aerodynamic pitch-to-thrust coupling reported in APE II (ref 7, app I) was investigated. Level-flight airspeeds from 45 to 150 knots true airspeed (KTAS) and climbs and descents from 70 to 100 KTAS were evaluated. With the PSA system ON, raising the thrust control rod resulted in a transient nose-down pitching moment, and lowering the thrust control rod resulted in a transient nose-up pitching moment. The ability of the PSA system to automatically compensate for this pitch-to-thrust coupling was a function of the magnitude and rate of the collective input. Regardless of airspeed or power setting, rapid inputs resulted in pitch attitude changes or pitch rates which required the pilot to make longitudinal cyclic inputs to assist the PSA system in maintaining constant airspeed (PRS A4). It is recommended that thrust control rod changes be made smoothly whenever possible, to minimize pilot effort during power changes. Correction of the pitch-to-thrust aerodynamic coupling when making thrust control rod changes is desirable for improved helicopter operation.

Maneuvering Flight

40. Within the scope of these tests, the maneuvering stability as defined by normal acceleration response and angular velocity response characteristics following aft longitudinal step inputs were similar to those reported in paragraph 46 of the APE II (ref 7, app I) and are satisfactory for Army use.

41. Banked turn flight characteristics with basic SAS were essentially the same as exhibited in APE II except that forward-head droop-stop conduct was not encountered during maneuvering turns at high altitude. The maneuvering flight characteristics with the PSA system ON/detent ON were similar to those experienced during the APE II basic SAS maneuvering. The pilot was continually required to

operate in and out of the detent position to maintain constant attitude and airspeed during constant-altitude or constant-power turns (PRS A5). Correction of these PSA system ON/detent ON maneuvering flight characteristics is desirable for improved helicopter operation.

42. Maneuvering flight characteristics with the PSA system ON/detent OFF were improved over both basic SAS, and the PSA system ON/detent ON, maneuvering flight. The pilot effort required to maintain constant pitch attitude and airspeed during banked turns was low. However, with the detent OFF, retrimming at airspeeds in excess of 5 knots above or below trim speed resulted in uncommanded pitch attitude changes for which pilot compensation was necessary (PRS A4). Correction of the PSA system ON/detent OFF uncommanded pitch attitude characteristics associated with retrimming operations is desirable for improved helicopter operation.

43. The sensitivity of the helicopter to small lateral control inputs about trim was significantly reduced in banked turns (para 34) (PRS A2). The ECP also provided an improved roll axis stability for bank angles within 5 degrees of wings level flight and would retain these banked or wing-level roll attitudes within approximately 2 degrees. This attitude retention feature also reduced the pilot's workload by allowing a "hands off" return to wing-level flight after a transient maneuver providing the centering release button was not depressed during the maneuver (PRS A3). The flying quality characteristics resulting from the incorporation of ECP 620 are satisfactory for Army use.

Takeoffs and Landings

44. Takeoff and landing flight characteristics were similar to those reported in APE II with the exception of the landing approaches and takeoffs with the PSA system ON and the detent ON/OFF. With the PSA system ON/detent ON, the retrimming pitching moments were small and did not degrade controllability when accelerating or decelerating. The detent ON flying qualities during the constant speed portion of landing approaches and takeoffs were degraded by turbulence in that the pilot was constantly moving the cyclic in and out of the detent band to maintain attitude and airspeed (PRS A4).

45. The detent OFF flying qualities during the constant speed portion of landing approaches and takeoffs provided the pilot with positive helicopter attitude control and are satisfactory for Army use (PRS A3).

46. With the detent OFF, retrimming pitching moments varied proportionally in magnitude with the airspeed above or below a stable trim speed. If retrimming was accomplished in excess of 5 knots from trim speed during takeoff or landing, the pitching moments were distracting to the pilot and degraded precise pitch control of the aircraft (PRS A5). It is recommended that during approaches to a landing or acceleration following a takeoff, the PSA system ON/detent ON switch be selected, and the PSA system switch be positioned to OFF or the centering release button be depressed. Correction of the detent OFF retrimming characteristics is desirable for improved helicopter operation.

Simulated Single Engine Failures

47. Simulated single engine failures were not performed during APE III or IV. The helicopter response to single engine failure is discussed ir reference 7, appendix I.

SAS OFF Flight

48. The SAS OFF flight was qualitatively evaluated to determine any changes in flying qualities due to incorporation of the PSA system. Complete SAS disengagement was accomplished by moving the emergency SAS release switch to the RELEASE position.

49. Generally, the SAS OFF/PSA system OFF forward flight characteristics are the same as reported in reference 7, appendix I, and meet the requirements of paragraph 3.5.9(d) of the military specification. The PSA system, a long-term response system, lags the pilot input to correct the short-term pitch rates during the SAS OFF flight and degrades the SAS OFF forward flight characteristics (PRS A4). Thus, the SAS OFF/PSA system ON flight characteristics of the CH-47C were unsatisfactory as compared to the SAS OFF/PSA system OFF characteristics during forward flight. The PSA system influence on the time available for pilot response during the dual SAS failure was not evaluated during these tests but is being investigated by the contractor during their SAS failure demonstration tests. The SAS OFF/PSA system ON flying qualities are not satisfactory for emergency operation. It is recommended that the PSA system be deactivated whenever the dual SAS failure occurs.

MISCELLANEOUS

Vibration

50. The APE IV vibration evaluation was conducted in three configurations as follows and the APE III vibration evaluation was conducted only in configurations (a) and (b).

a. 33,000-pound grwt troop ballast configuration for vibration compliance as specified in deviation 12 of the detail specification.

b. Unballasted configuration for Acceptance Document data acquisition.

c. 46,000-pound alternate design grwt configuration for determination of the effect of gross weight on vibration characteristics.

51. The three-per-revolution vertical vibrations were the most significant with respect to the operational suitability of the aircraft. Qualitative evaluations of the three-per-revolution cockpit vibration levels were made throughout the APE III and IV tests and generally substantiated the quantitative results. Quantitative vibration compliance and alternate design grwt vibration data were recorded by means of a magnetic tape recorder mounted on an instrumentation table located centrally in the cargo compartment. The instrumentation table and accelerometer pickups are shown in photographs 5 to 15, appendix VI. Vibration compliance test conditions conformed to those specified in deviation 12 of the detail specification (ref 5, app I). These tests conditions were also used to obtain vibration data at alternate design grwt.

52. The vibration compliance and alternate design grwt one-per-revolution and three-per-revolution vibration level data recorded during the APE IV are presented in figures 38 through 67, appendix II, and show that within the operating limitations of the helicopter the vibration levels were independent of fuel weight and rotor speed in most cases. Comparative summaries of the three-per-revolution vibration specification compliance data for level flight, partial power descents, accelerations and decelerations are presented in tables 3 through 6, respectively. Only the three-per-revolution vibration data are tabulated, since all one-per-revolution vibrations met the requirements of deviation 12 of the detail specification during both evaluation tests. Compliance was based on the 85-percent harmonic level of the vibration data analyzed over a 20-rotor cycle sample at a 235-rpm rotor speed for stabilized flight and the 100-percent level of data for transient conditions. During APE III, gust upsets or

pilot inputs caused cycling or bottoming of the self-tuning vibration absorbers (STVA) at airspeeds of approximately 145 KTAS and above in the troop loaded and unballasted configurations. Failure to meet the requirements of the detail specification during APE III as indicated in table 3 resulted in modification of the fuel tank isolation mounts (ECP 553R2), incorporation of improved self-tuning vibration absorbers (ECP 554R3) and installation of elastomer windshield post mounts (ECP 554R3). During APE IV the three-per-revolution vibration levels in the cockpit and cabin areas were less than those of APE III and met the requirements of detail specification. Qualitatively, the three-per-revolution vertical vibrations recorded at the pilot and copilot's heel slides were fatiguing at sustained airspeeds of 150 KTAS and above. Correction of this characteristic is desirable for improved helicopter operation (PRS A4).

Table 3. Level Flight Vibration Specification Compliance.[1]

Station	Axis	Vibration[2] (g)		Percentage Above Spec. Limit (%)	
		APE III	APE IV	APE III	APE IV
320 left	Vertical	0.260	0.13	30.0	--
320 left	Lateral	0.100	0.14	--	--
320 right	Vertical	0.350	0.15	75.0	--
95 center	Vertical	0.080	0.09	--	--
95 center	Lateral	0.100	0.16	--	--
Pilot's collective	Vertical	0.500	0.28	25.0	--
Copilot's collective	Vertical	0.560	0.30	40.0	--
Pilot's cyclic	Vertical	0.300	0.19	--	--
Pilot's cyclic	Longitudinal	0.180	0.12	--	--
Copilot's cyclic	Lateral	0.130	[3]0.68	--	70
Copilot's cyclic	Longitudinal	0.550	0.18	37.5	--
Pilot's pedal	Longitudinal	0.470	0.17	17.5	--
Copilot's pedal	Longitudinal	0.470	0.19	17.5	--
Pilot's heel	Vertical	0.807	0.27	102.0	--
Copilot's heel	Vertical	0.728	0.16	82.0	--

[1]Three-per-revolution levels only; one-per-revolution levels all met specification requirements.
[2]Eighty-five percent of the harmonic level of analyzed data; 20-rotor cycle sample.
[3]Data taken hands off; vibration level was below specification with hands on.

Table 4. Partial Power Descent Vibration Specification Compliance.

Station	Axis	Maximum Vibration (g)		
		APE III	APE IV	Specification Limits
95 center	Vertical	0.09	0.11	0.40
95 center	Lateral	0.10	--	0.40
320 left	Vertical	0.16	0.09	0.40
320 left	Lateral	0.07	--	0.40
320 right	Vertical	0.22	0.12	0.40

Table 5. Acceleration Vibration Specification Compliance.

Station	Axis	Maximum Vibration (g)		
		APE III	APE IV	Specification Limits
95 center	Vertical	0.14	0.130	0.40
95 center	Lateral	0.10	--	0.40
320 left	Vertical	0.20	0.09	0.40
320 left	Lateral	0.12	--	0.40
320 right	Vertical	0.29	0.08	0.40

Table 6. Deceleration Vibration Specification Compliance.

Station	Axis	Maximum Vibration (g)		
		APE III	APE IV	Specification Limits
95 center	Vertical	0.310	0.14	0.40
95 center	Lateral	0.190	--	0.40
320 left	Vertical	0.260	0.08	0.40
320 left	Lateral	0.140	--	0.40
320 right	Vertical	0.405	0.04	0.40

53. The Acceptance Document vibration data (one- and three-per-revolution) were obtained by means of a vibration amplitude detection indicator (VADI) through vertical vibration pickups located at fuselage station (FS) 320 left, butt line (BL) 44, FS 95 center and FS 50 right, BL 30. The data were recorded by hand from a VADI gage in the cockpit. Photo 16, appendix VI, shows the VADI installation. Acceptance Document test conditions were based on those specified in reference 9, appendix I.

54. The Acceptance Document vibration levels recorded during APE IV are presented in figures 68 through 70; appendix II. A comparative summary of data acquired during APE III and IV is presented in table 7 and shows that the APE IV levels were significantly reduced from those recorded in APE III. These data were furnished to USAAVSCOM for negotiation of the vibration portion of the CH-47C Acceptance Document negotiations with the contractor. It was also recommended that the tuning rate of the STVA's be evaluated at airspeeds of 100 to 120 KTAS during acceptance flights.

Table 7. Acceptance Document Comparative Summary.

Station	Rotor Speed (rpm)	Vertical[1]		Vertical[2]	
		APE III	APE IV	APE III	APE IV
50 right	235	0.080	0.025	0.530	0.215
50 right	245	0.110	0.030	0.380	0.220
50 right	250	0.135	0.050	0.270	0.240
95 center	235	0.070	0.030	0.145	0.040
95 center	245	0.065	0.045	0.100	0.050
95 center	250	0.155	0.060	0.105	0.070
320 left	235	0.030	0.020	0.470	0.350
320 left	245	0.090	0.025	0.520	0.300
320 left	250	0.035	0.045	0.620	0.340

[1]One-per-revolution vertical maximum recorded value, independent of airspeed.

[2]Three-per-revolution vertical maximum recorded value, independent of airspeed.

Noise

55. Noise-level tests were conducted by the US Army Human Engineering Laboratories (USAHEL), Aberdeen Proving Ground, Maryland. Tests were conducted on the CH-47C for maximum continous power and normal cruise power conditions, and the data were compared to noise-level data obtained on the CH-47B.

56. The results of the tests are contained in reference 11, appendix I, and show that there was very little difference in noise level between the CH-47B and the CH-47C aircraft even though the rotor speed of the CH-47C helicopter was higher than that of the CH-47B. In most cases above approximately 2000 hertz (hz), the CH-47C noise level was slightly higher than that of the CH-47B. The noise levels measured in the CH-47C helicopter exceeded the requirement of Military Specification MIL-A-8806A with the highest occurring below 100 hz and above 7000 hz. In most cases below 100 hz and above 7000 hz, the noise levels measured in the CH-47C helicopter also exceeded the requirements of deviation 66 of the detail specification. Correction of the CH-47C noise-level characteristics is desirable for improved helicopter operation.

57. The blade "bang" phenomenon (a staccato rotor blade noise experienced at high power settings and 245 rpm rotor speed) had a fatiguing effect on the air crew and was distracting during the performance of required duties (PRS A5). It is recommended in reference 11, appendix I, that efforts be continued to reduce over-all noise levels in this type aircraft. Until noise has been reduced to satisfactory levels, it is recommended that flight personnel wear ear plugs in addition to flight helmets. Correction of the CH-47C blade "bang" phenomenon is desirable for improved helicopter operation.

Thrust Control Rod Sensitivity

58. The engine torque control was imprecise for most conditions tested. The pilot was required to set torque with the thrust control rod at a position higher than required for a given flight condition. When torque was set at a desired value and the magnetic brake trigger released, torque would decrease. However, torque control was improved over that reported in APE II. Figure 71, appendix II, shows a comparison of the required torque oversets disclosed by APE II and III. During APE II to obtain a torque setting of 78 percent (dual engine transmission limit), a torque overset of 2 percent was required. As shown in figure 71, the thrust control rod sensitivity was a 10-percent engine torque increase for an approximate 5-percent (0.145 inch) collective motion in the 38- to 70-percent engine torque range. Above 70-percent engine torque, the sensitivity increased to 10-percent engine torque for an approximate 3-percent (0.27 inch)

collective motion. Excessive thrust control rod sensitivity required that the pilot command transient transmission overtorques to obtain the torque limit (78 percent). Extreme pilot effort was required to stay within the operating torque limit and distracted the pilot's attention from other necessary cockpit duties (PRS A5). Correction of the high thrust control rod sensitivity is desirable for improved helicopter operation.

Auxiliary Power Unit Operation

59. During the course of the APE III and IV tests, numerous uncommanded shutdowns of the auxiliary power unit (APU) occurred during ground operations. The direction of the wind did not appear to be of significant importance since shutdowns occurred with quartering wind, tailwind and headwind conditions and also during starting and shutdown portions of the aircraft operation. The cause of these shutdowns was attributed to extreme temperatures in the APU combustion chamber due to the ingestion of exhaust gas from the No. 2 engine. Often these uncommanded shutdowns occurred without the pilot's immediate awareness of the situation since the location of the APU high exhaust temperature warning light is on the center overhead console panel outside of the pilot's normal field of vision. Also, there is no light on the caution panel to indicate to the pilot that the APU is in operation. The operator's manual provides a procedure to be followed when starting the APU prior to engine shutdown but does not contain a specific procedure to be followed during engine start operations. When shutdown of the APU occurs while the No. 1 and 2 engines are being accelerated from idle to the flight speed, the possibility exists that the sprag clutch or the accessory gear box quill shaft will incur damage. When an APU shutdown occurs, the accessory gear box quill shaft rapidly decelerates until the aft transmission, accelerating from ground to flight speed, engages the sprag clutch on the quill shaft. Engagements of this nature subject the quill shaft to abnormally high transient torques. Repitition of this condition may eventually lead to failure of the quill shaft. Failure of the quill shaft causes loss of both flight control hydraulic systems, and in flight, causes catastrophic loss of the aircraft. The problem of uncommanded APU shutdown has existed with all models of the CH-47; however, the incorporation of the T55-L-11 engines with higher power output and the accompanying increased exhaust gas temperature has created an increasingly severe problem. Hot day conditions further aggravate the problem. As an interim measure, it is recommended that all CH-47C pilots be instructed to start the No. 1 engine and bring the rotor system to flight speed prior to starting the No. 2 engine. It is further recommended that an APU system be developed which is free from uncommanded shutdowns. The incorporation of the APU ON caution panel

light is also recommended. Correction of the uncommanded APU shutdown problem is desirable for improved helicopter safety.

Fuel System Quantity Calibration

60. The two production CH-47C helicopters tested during APE III and IV consistently showed the fuel quantity indications which were approximately 350 pounds lower than the quantity measured in the tanks. The contractor stated that fuel system quantity calibration for production aircraft was based upon a JP-4 fuel with maximum specification density at -65°F. Such a calibration always indicates to the pilot a conservative quantity of fuel available. However, it also causes the pilot to underestimate the takeoff grwt of the aircraft by the amount of this conservatism. The aircraft fuel system incorporates left fuel low and right fuel low caution lights which are independent of the fuel calibration system and illuminate when the fuel level in the tanks reaches approximately 20 minutes of flight time remaining at normal cruise power. Therefore, the conservative quantity is not necessary from a flight safety standpoint. Since gross weight of the aircraft can become a critical factor during hot day and high-altitude operation, it is desirable to have the fuel system quantity indicator as accurate as possible. Correction of the fuel system quantity calibration procedure is desirable for improved helicopter operation.

CONCLUSIONS

GENERAL

61. The following conclusions were reached upon completion of the APE III and IV testing:

a. The PSA system enhanced the longitudinal handling qualities to the degree that hands-off stabilized climbing, descending and level flight were possible (para 14).

b. The incorporation of ECP's 598, 610, 611R1 and 620 significantly improved the trimmability, the static and dynamic longitudinal stability and the lateral-directional stability characteristics reported in APE II (paras 20, 30, 32, 36, 37 and 43).

c. Vibration levels measured during APE IV were significantly reduced from those measured during APE III (paras 52 and 54).

d. Noise levels were unsatisfactory in the CH-47C aircraft (para 56).

e. Noise-level comparisons between the CH-47B and CH-47C showed very little difference even though the rotor speed of the CH-47C helicopter was higher than that of the CH-47B (para 56).

f. Torque control was improved over that reported in APE II, but thrust control rod sensitivity remained high (para 58).

SHORTCOMINGS AFFECTING MISSION ACCOMPLISHMENT

62. Correction of the following shortcomings is desirable for improved helicopter operation.

a. Uncommanded pitch attitude changes associated with retrimming operations in the PSA system ON/detent OFF mode (paras 30, 42 and 46).

b. Unstable longitudinal trim position gradients (para 24).

c. Pitch-to-thrust coupling when making thrust control rod changes (para 39).

d. Static longitudinal stability characteristics with the PSA system OFF (para 28).

e. The PSA system ON/detent ON static longitudinal stability characteristics (para 29).

f. Basic SAS longitudinal dynamic stability characteristics (para 37).

g. The PSA system airspeed and attitude feedback signal failure characteristic (para 38).

i. The PSA system ON/detent ON degraded maneuvering flight characteristics during constant altitude or constant power turns (para 41).

j. Degraded flying qualities during the constant speed portion of landing approached with the PSA system ON in the detent ON mode (para 44).

k. Three-per-revolution vertical vibrations at the pilot and copilot's heel slides for sustained airspeeds of 150 KTAS and above (para 52).

l. Noise-level characteristics (para 56).

m. Blade "bang" phenomenon (para 57).

n. High, thrust control rod sensitivity (para 58).

o. Uncommanded APU shutdown (para 59).

p. Inaccurate fuel quantity indicators (para 60).

SPECIFICATION COMPLIANCE

63. Within the scope of these tests, the stability and control, vibration and noise-level characteristics of the CH-47C met the requirements of the military specification or deviations of the detail specification except as listed below:

a. Deviations 5 and 11 of the detail specification: With the PSA system OFF, control position gradients remain unstable as previously reported in APE II (para 28).

b. Paragraphs 3.2.11 and 3.6.1.2 of the military specification: With the PSA system OFF, the pitch response to simulated gust inputs was divergent (para 37).

c. Deviation 66 of the detail specification: In most cases below 100 Hz and above 7000 Hz the noise levels exceeded the requirements (para 56).

RECOMMENDATIONS

64. Shortcomings should be corrected at the earliest possible time.

65. Thrust control rod changes should be made at a gradual rate whenever possible to minimize pilot effort (para 39).

66. A note should be incorporated in the operator's manual: "When operating the PSA system ON/detent OFF, depress the centering device release button prior to initiating an airspeed and/or attitude change and release the button only after stabilizing at a new flight condition" (para 30).

67. Automatic deactivation of the PSA system should occur if failure of either feedback signal occurs (para 38).

68. A PSA system failure caution panel light should be incorporated (para 38).

69. The PSA system should be deactivated whenever dual SAS failure occurs (para 49).

70. A sustained effort to reduce overall noise levels in this type aircraft should be continued (para 57).

71. Flight personnel should wear ear plugs in addition to flight helmets until noise has been reduced to acceptable levels (para 57).

72. All CH-47C pilots should be instructed to start No. 1 engine and bring the rotor to flight speed prior to starting No. 2 engine (para 59).

73. An APU system which is normally free from uncommanded shutdowns should be developed (para 59).

74. An APU ON caution panel light should be incorporated (para 59).

APPENDIX I. REFERENCES

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7. Final Report, USAAVNTA, Project No. 66-28, *Engineering Flight Test of the YCH-47C Medium Transport Helicopter, Army Preliminary Evaluation II*, February 1969.

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11. Letter Report, Acoustical Research Branch, Engineering Research Laboratory, US Army Human Engineering Laboratories, No. 95, *Interior Noise Evaluation of the CH-47C Helicopter*, January 1969.

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13. Specification, 114-PJ-608, Vertol Division of the Boeing Company, *Acceptance Test Procedures, Flight Test CH-47B*, Revision J, July 1968.

14. Flight Test Manual, US Navy Test Pilot School, FTM No. 101, *Helicopter Stability and Control*, 10 June 1968.

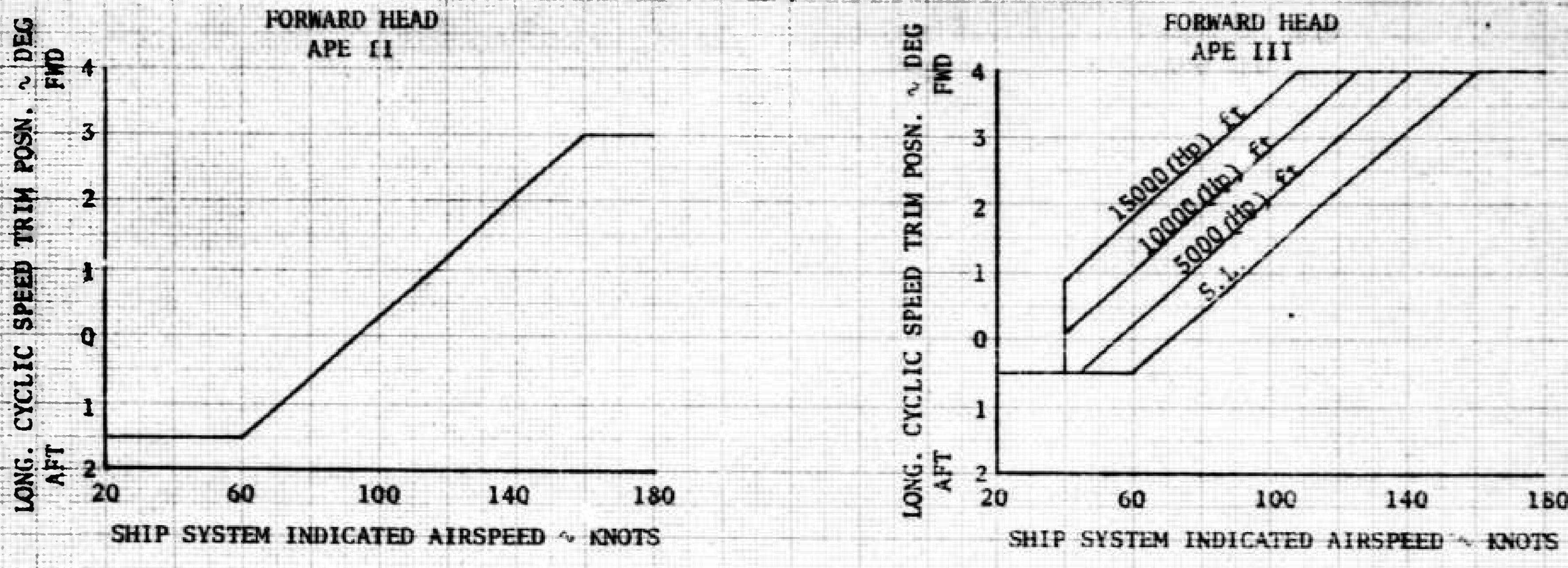
15. Letter, USAASTA, SAVTE-TE, subject: Evaluation of the CH-47C Modified Fuel Controls, 26 May 1969.

APPENDIX II. TEST DATA

FIGURE 1

COMPARISON OF APE II AND APE III

LONGITUDINAL CYCLIC SPEED TRIM SCHEDULE



NOTE: 1. AFT HEAD LONGITUDINAL CYCLIC SPEED TRIM SCHEDULES FOR APE II AND APE III WERE IDENTICAL. THE SCHEDULE IS SHOWN IN FIGURE 2.

2. DEGREES, MEASURED FROM MAST CENTER LINE.

FIGURE 2
LONGITUDINAL CYCLIC TRIM SCHEDULE
YCH-47C USA S/N 66-19121

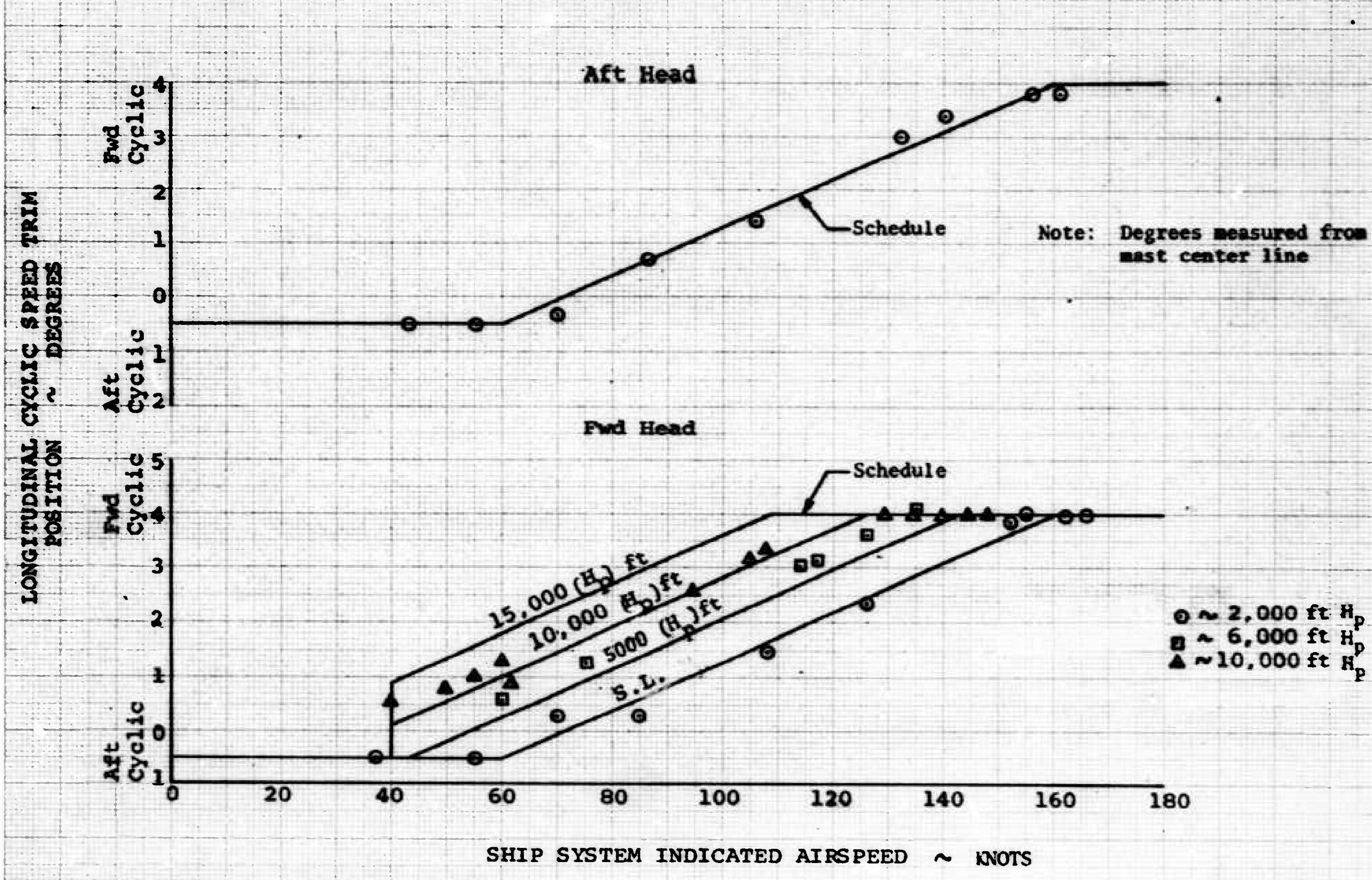


FIGURE 3
DIFFERENTIAL COLLECTIVE PITCH SCHEDULE
YCH-47C USA S/N 66-19121

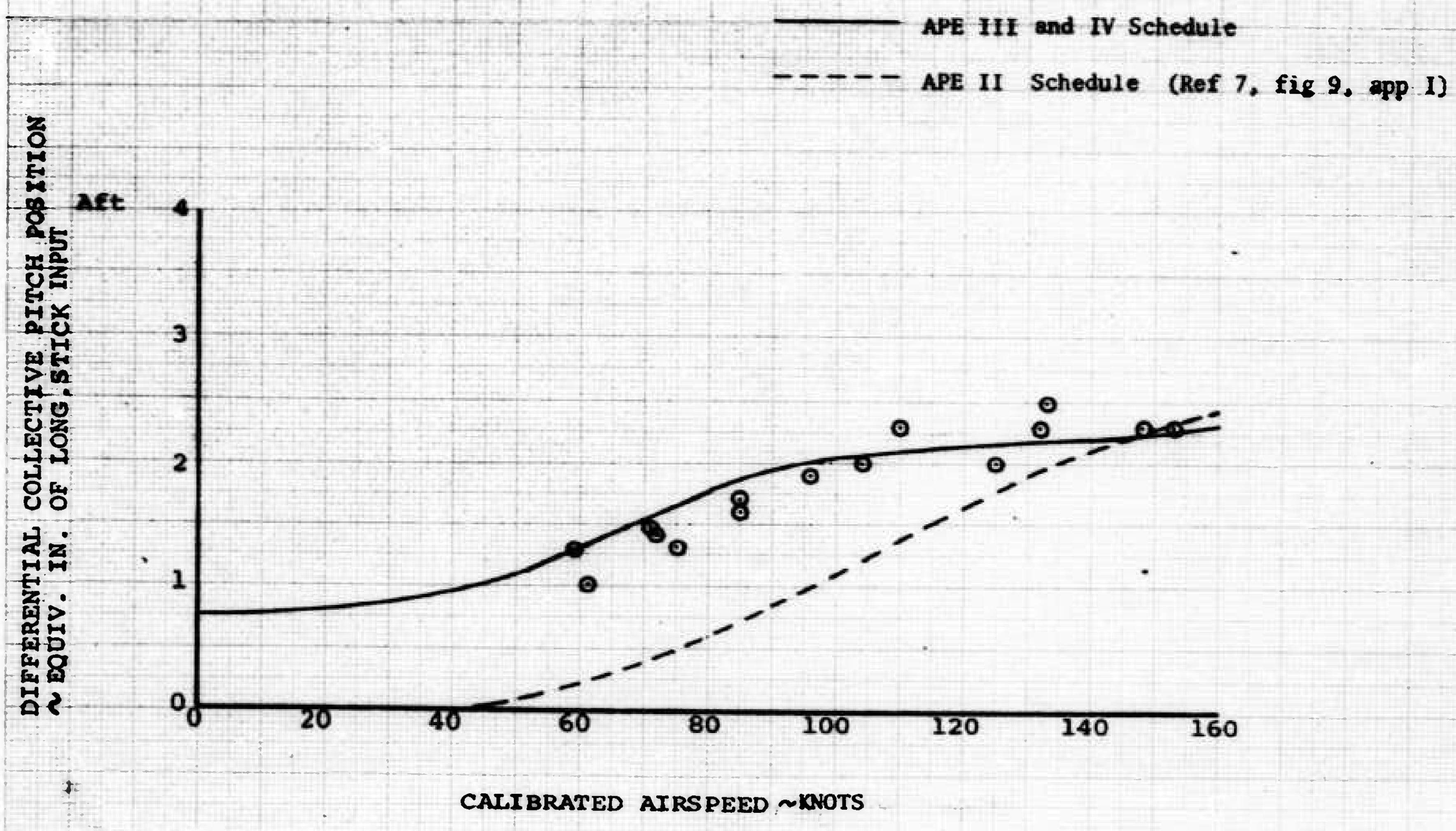


FIGURE 4
CONTROL POSITION TRIM CURVES
YCH-47C USA S/N 66-19121

SYM	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN.
○	LEVEL	37850	236	2800	5.8 IN AFT
⊡	LEVEL	35900	236	10400	6.8 IN AFT

Note: 1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS configuration = ON
3. Detent system inoperative
4. PSA Configuration = ON
5. Tails denote - DCP off.
6. Control travel shown in Appendix IV.

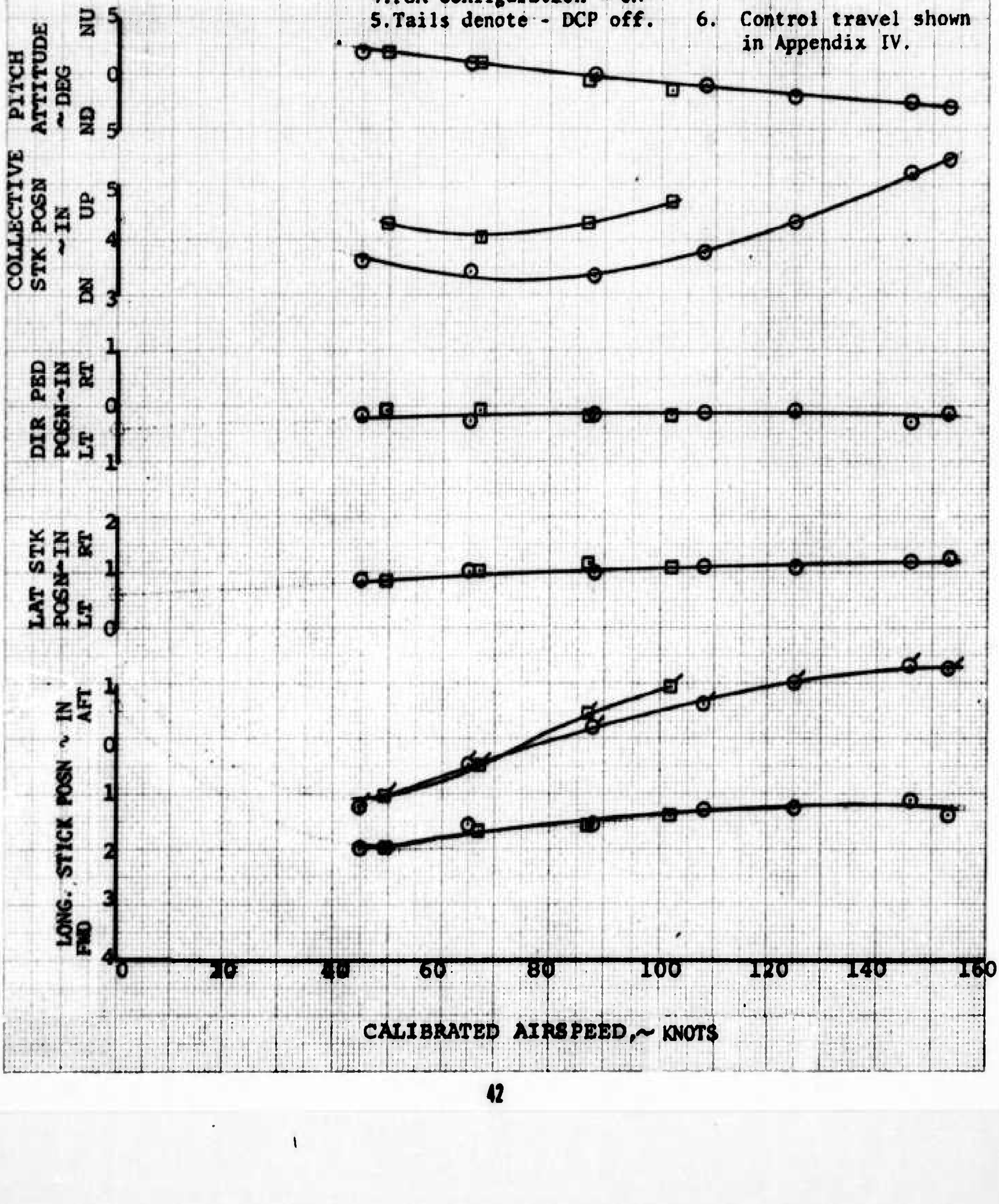


FIGURE 5
CONTROL POSITION TRIM CURVES
YCH-47C USA S/N 66-19121

SYM	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN.
·	LEVEL	46780	246	500	3.4 AFT

Note:
1. Speed Trim (DCP and Long. Cyclic) = Auto
2. SAS and PSA = ON
3. Shaded symbols denote trim points
4. Detent system inoperative
5. Tails denote DCP off (calculated)
6. Control travel shown in Appendix IV.

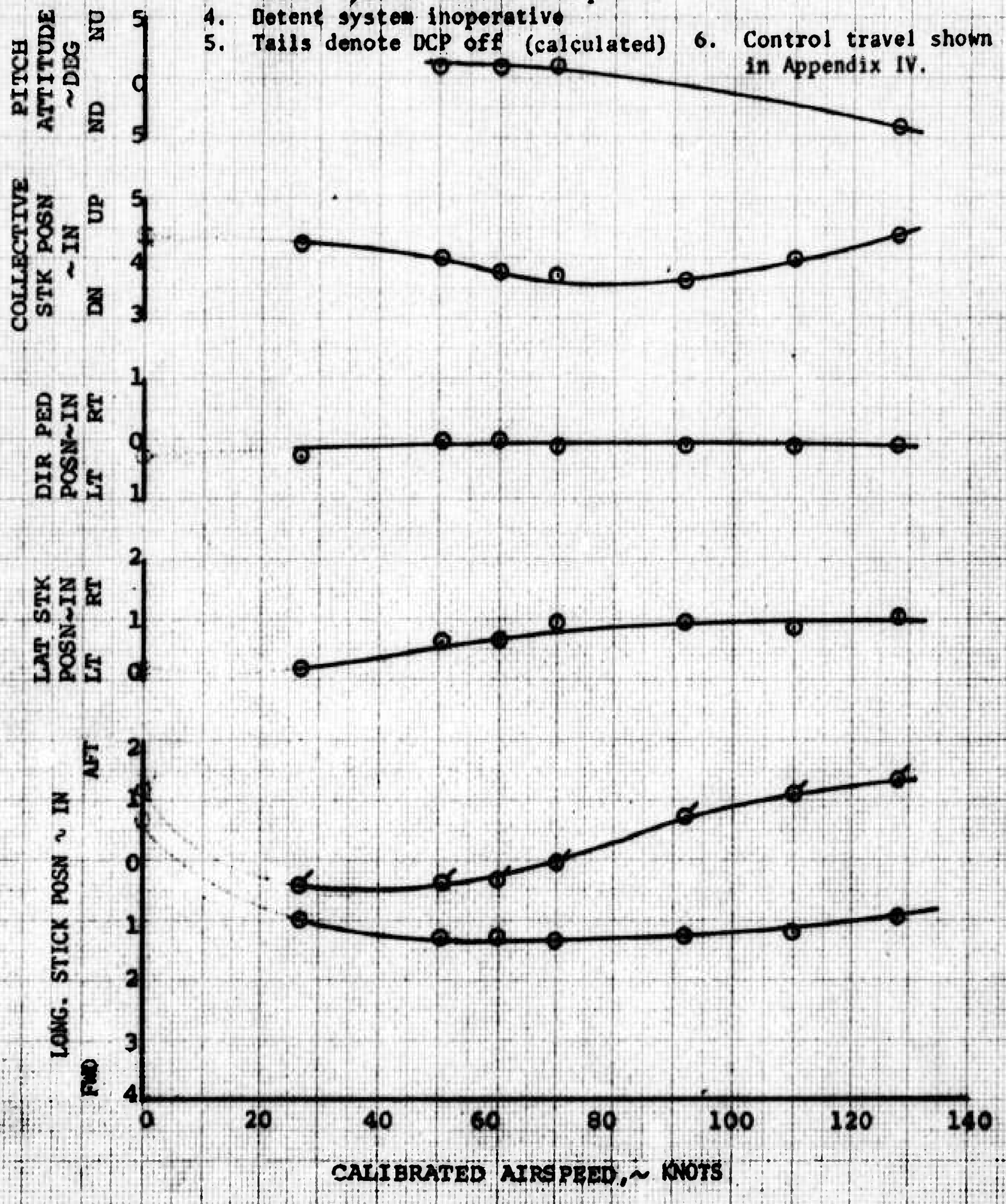


FIGURE 6
STATIC LONGITUDINAL COLLECTIVE - FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
⊙	72	LEVEL	46360	247	7700	3.5 AFT	4.67

Note:
1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS configuration = ON
3. Shaded symbols denote trim points
4. Detent system operative
5. PSA configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV.

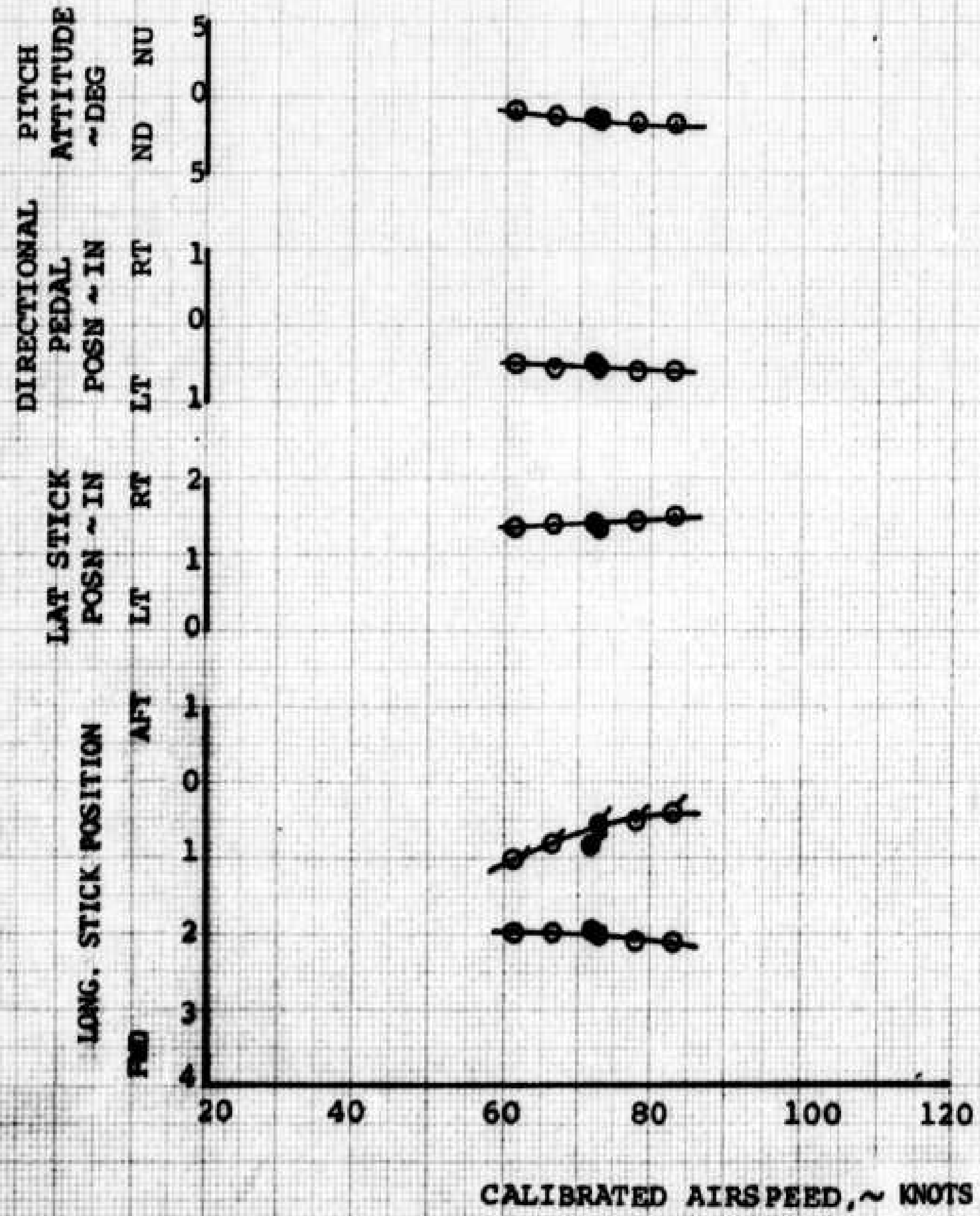


FIGURE 7

STATIC LONGITUDINAL COLLECTIVE - FIXED STABILITY

YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~ KCAS.	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
▢	61	Level	36140	246	13710	6.9 Aft	4.48
○	75	Level	37380	246	13910	6.2 Aft	4.71

Note:
1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system operative
5. PSA Configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV

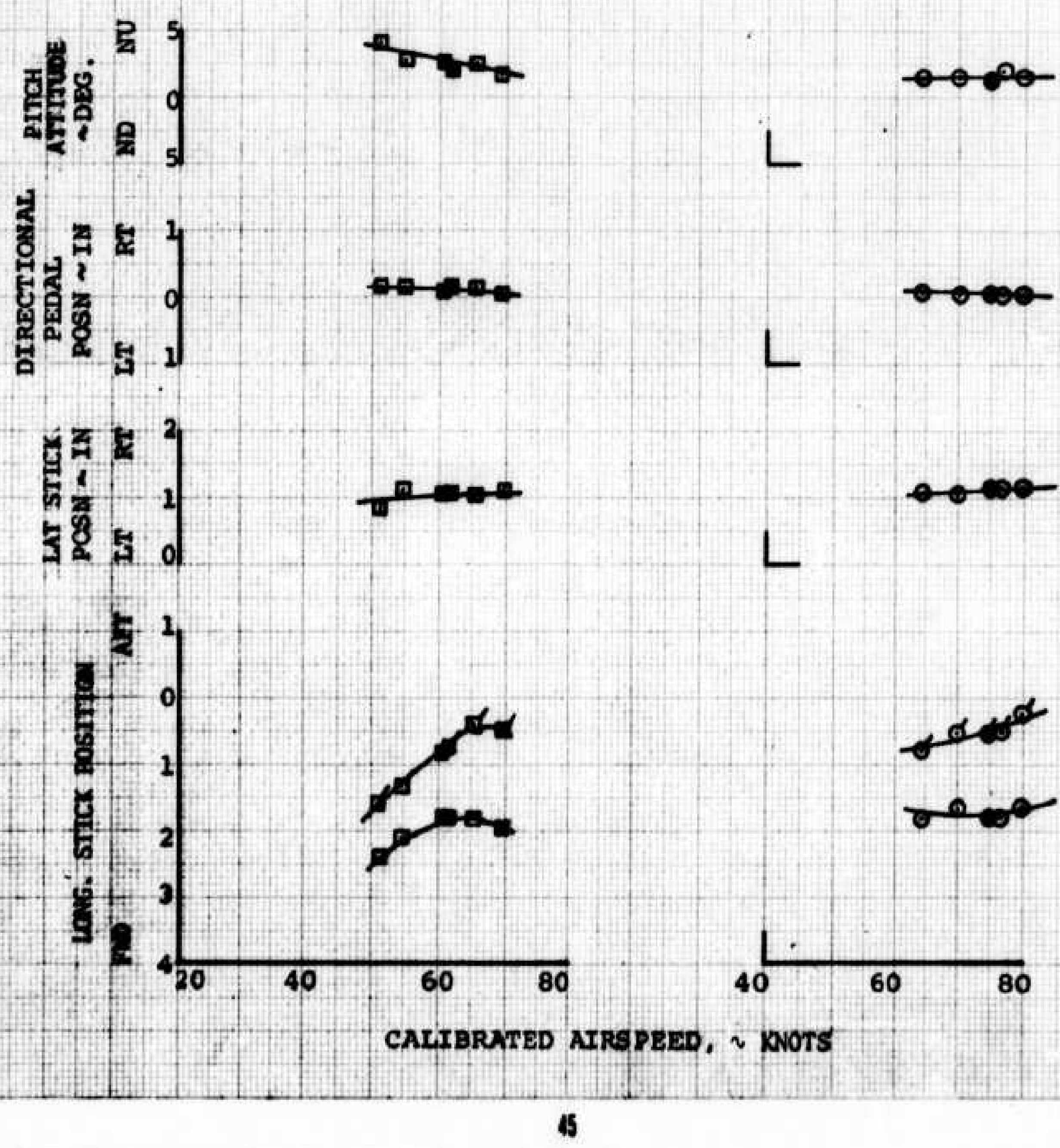


FIGURE 8
STATIC LONGITUDINAL COLLECTIVE - FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
▲	59	Level	42400	246	3020	5.4 Aft	4.00
⊡	85 (V_{cruise})	Level	43180	246	3540	5.2 Aft	3.92
⊙	132 (V_{NE})	Level	43650	246	4060	5.0 Aft	5.01

Note: 1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system operative
5. PSA Configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV

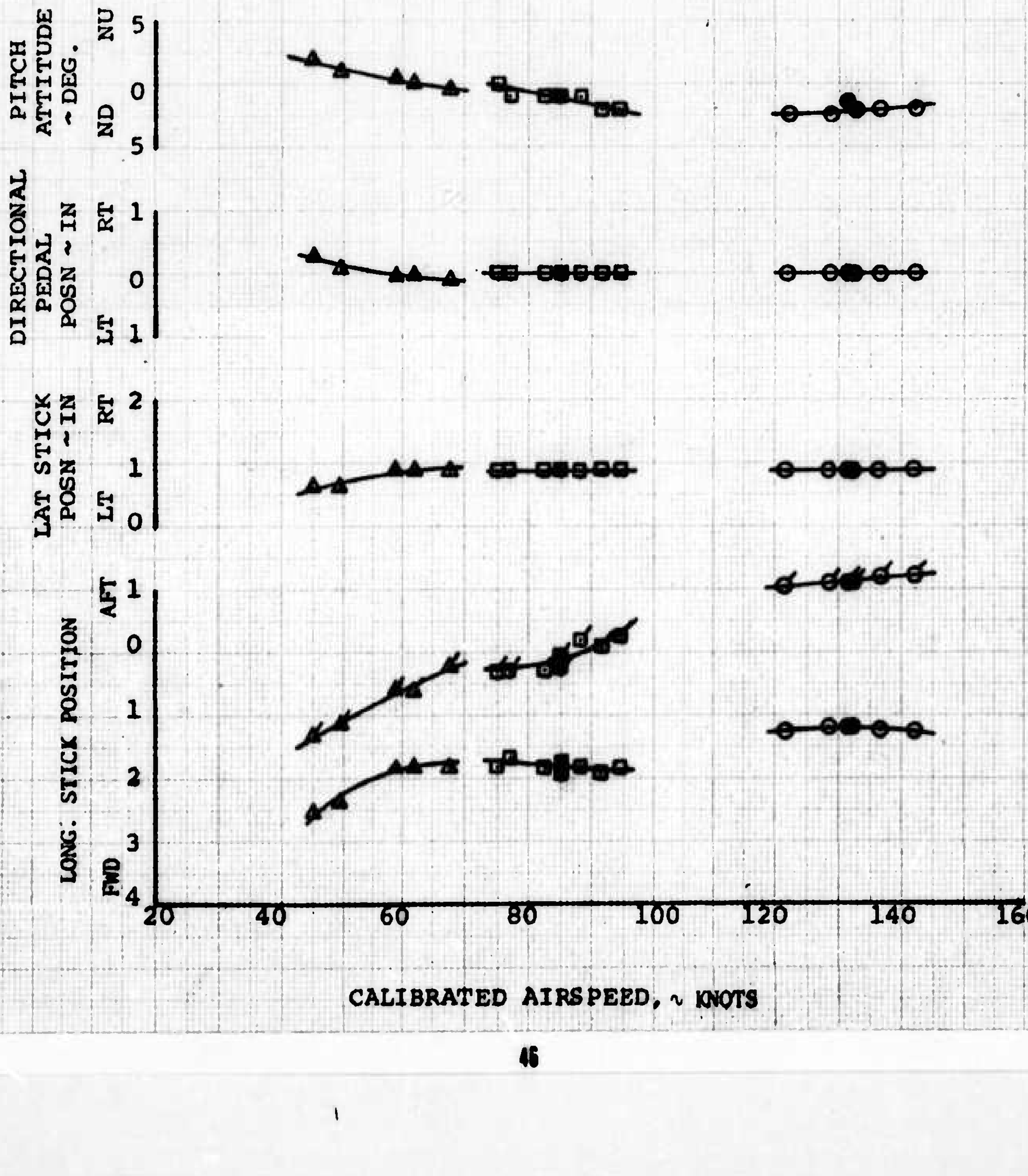


FIGURE 9
STATIC LONGITUDINAL COLLECTIVE - FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
▲	77 (V_{MinPwr})	Level	33400	238	4340	8.4 Aft	3.38
⊡	125 (V_{cruise})	Level	33930	236	4470	8.1 Aft	4.58
⊙	147	Level	34400	236	4280	7.8 Aft	5.56

Note:
1. Speed trim (DCP and Long. Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system operative
5. PSA Configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV.

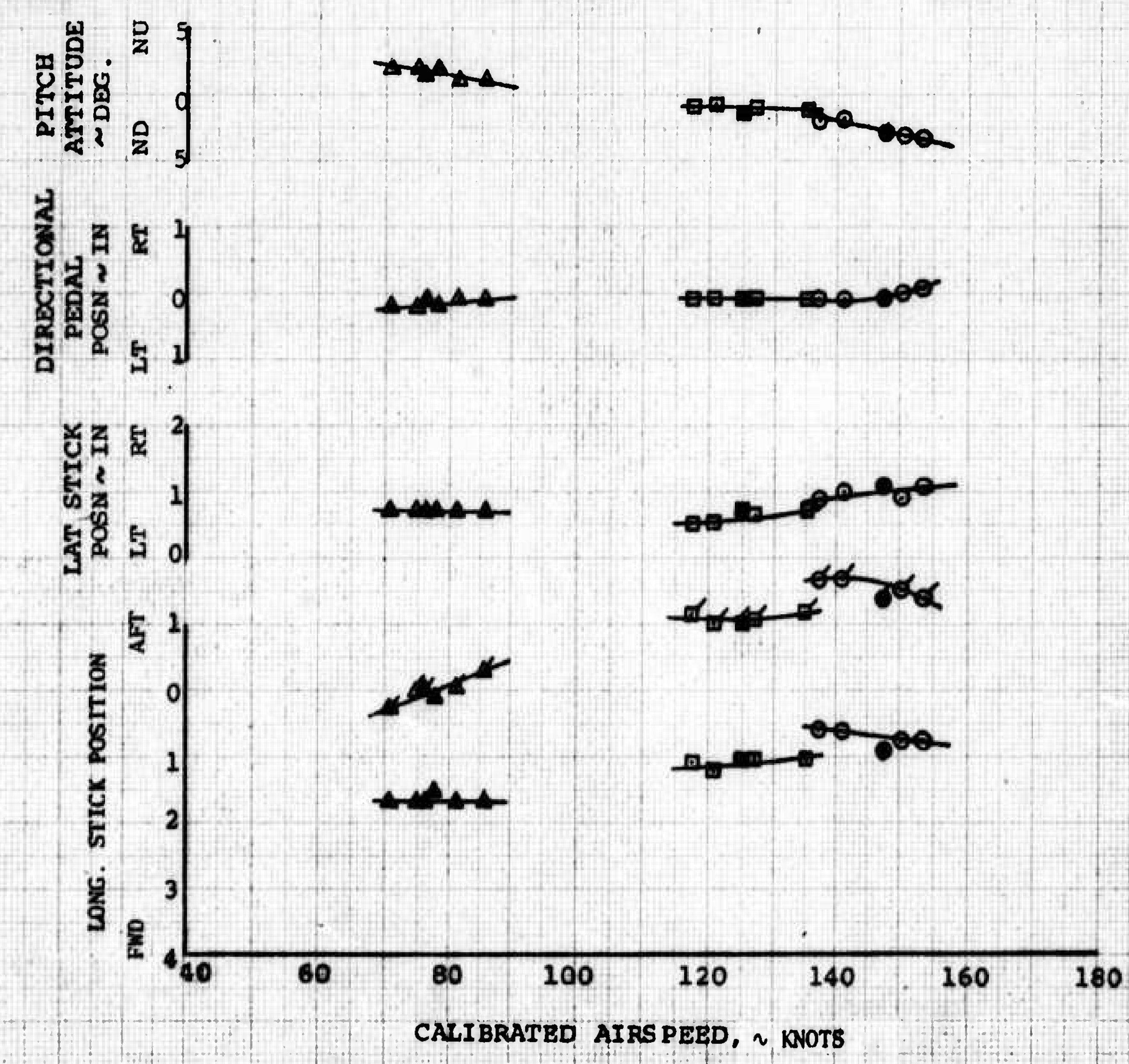


FIGURE 10

STATIC LONGITUDINAL COLLECTIVE - FIXED STABILITY

YCH-47C USA S/N 66-19121

SYM	SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
△	57	Level	41910	248	3970	5.9 Aft	3.65
⊡	85 (V_{MinPwr})	Level	42630	246	3780	5.2 Aft	3.63
⊙	132	Level	43165	247	5000	4.8 Aft	4.88

Note:
1. Speed Trim (DCP and Long. Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points.
4. Detent system inoperative
5. PSA Configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV.

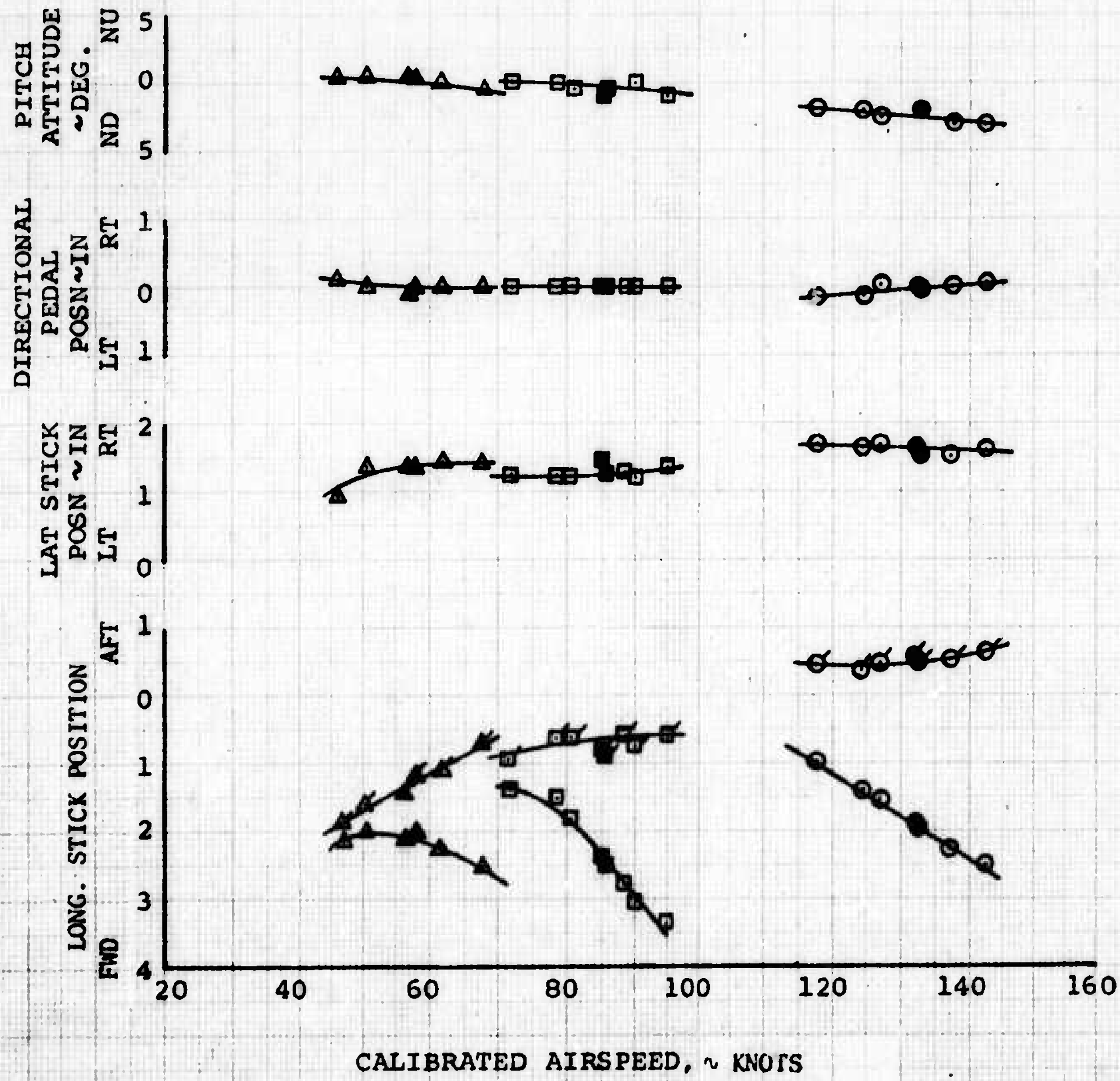


FIGURE 11

STATIC LONGITUDINAL COLLECTIVE - FIXED STABILITY

YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	SPEED ~ RPM	DENSITY ALT ~FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
⊡	57	Level	36910	246	13400	6.4 Aft	4.46
⊙	71	Level	37260	246	13450	6.2 Aft	4.45

Note:
1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system inoperative
5. PSA Configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV.

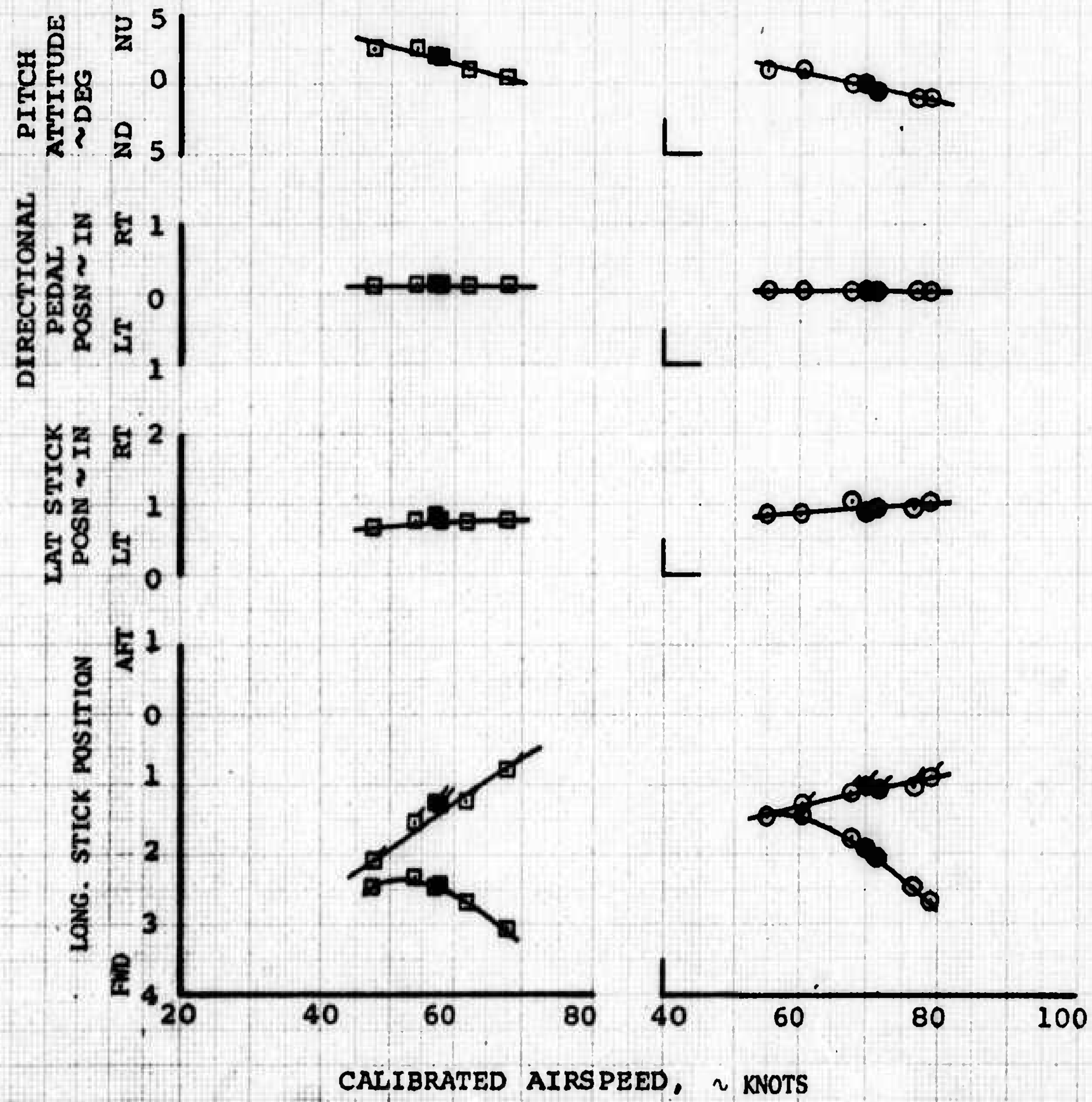


FIGURE 12
STATIC LONGITUDINAL COLLECTIVE-FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
▲	73 (V_{MinPwr})	Level	32330	235	4700	8.7 Aft	3.25
■	127 (V_{Cruise})	Level	35540	237	5100	7.2 Aft	4.78
⊙	144	Level	36020	237	5000	7.0 Aft	5.71

Note:
1. Speed trim (DCP and Long Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system inoperative
5. PSA Configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV.

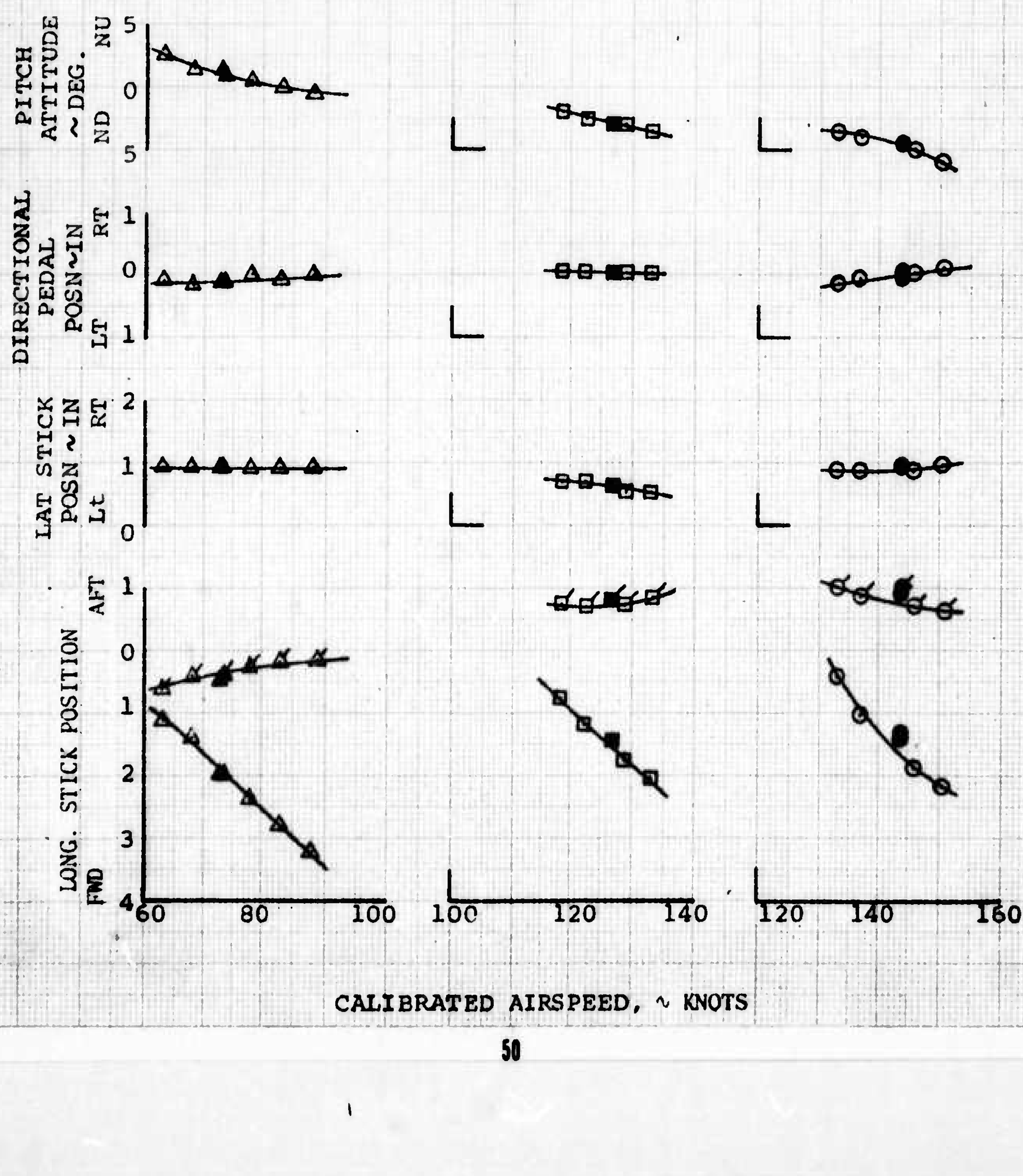


FIGURE 13
STATIC LONGITUDINAL COLLECTIVE-FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	ROTOR AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
□	72 ($V_{Min\ Pwr}$)	Level	36350	236	10400	6.7 Aft	4.32
⊙	98	Level	36590	236	10300	6.5 Aft	4.76

Note:
1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system inoperative
5. PSA Configuration = ON
6. Tails denote - DCP off.
7. Control travel shown in Appendix IV.

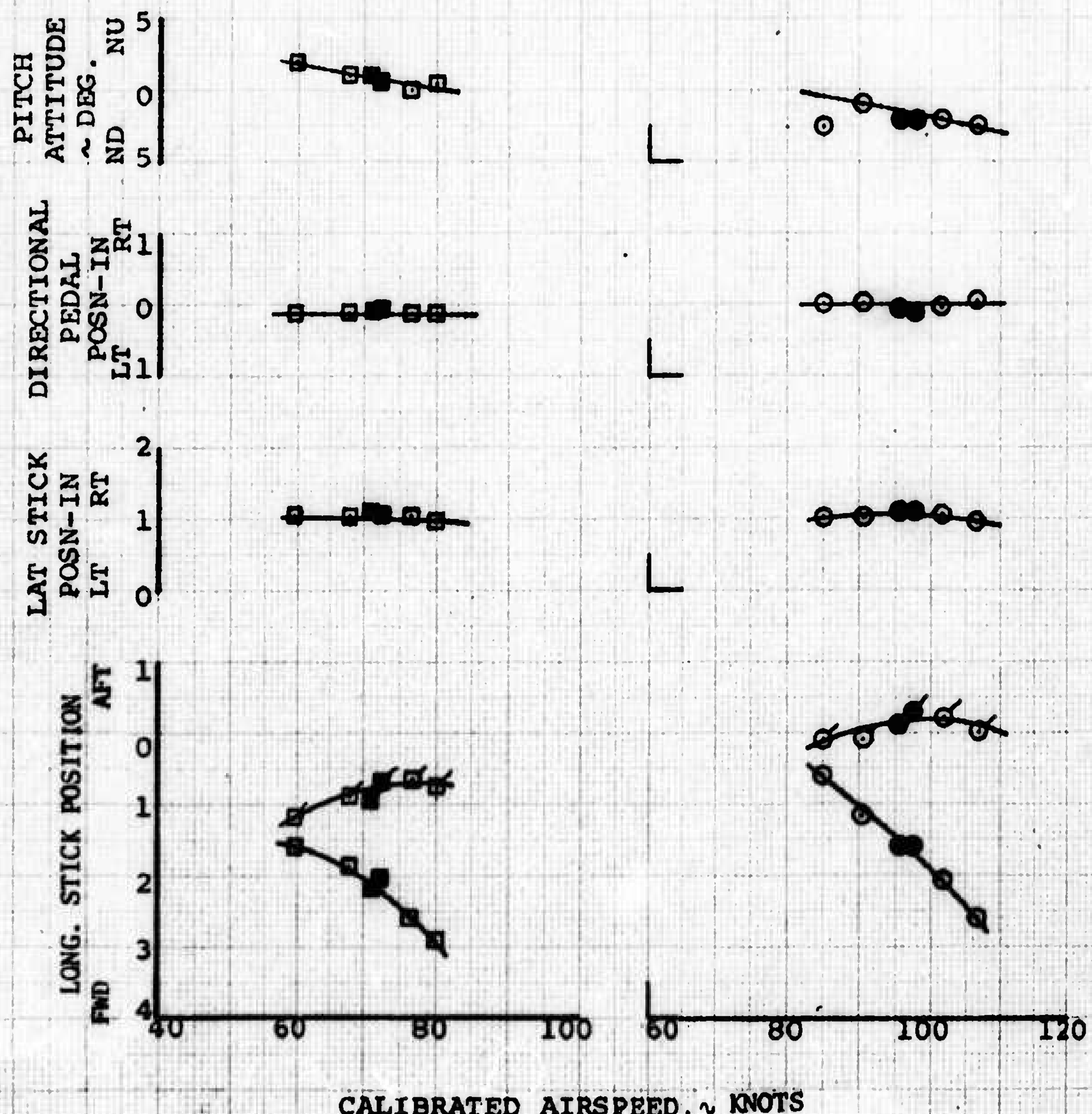


FIGURE 14
STATIC LONGITUDINAL COLLECTIVE-FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
□	76	Level	45770	247	7900	3.8 Aft	4.43
○	142	Level	41460	247	2200	5.9 Aft	4.87

Note:
1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system inoperative
5. PSA Configuration = ON
6. Tails denote - DCP off
7. Control travel shown in Appendix IV.

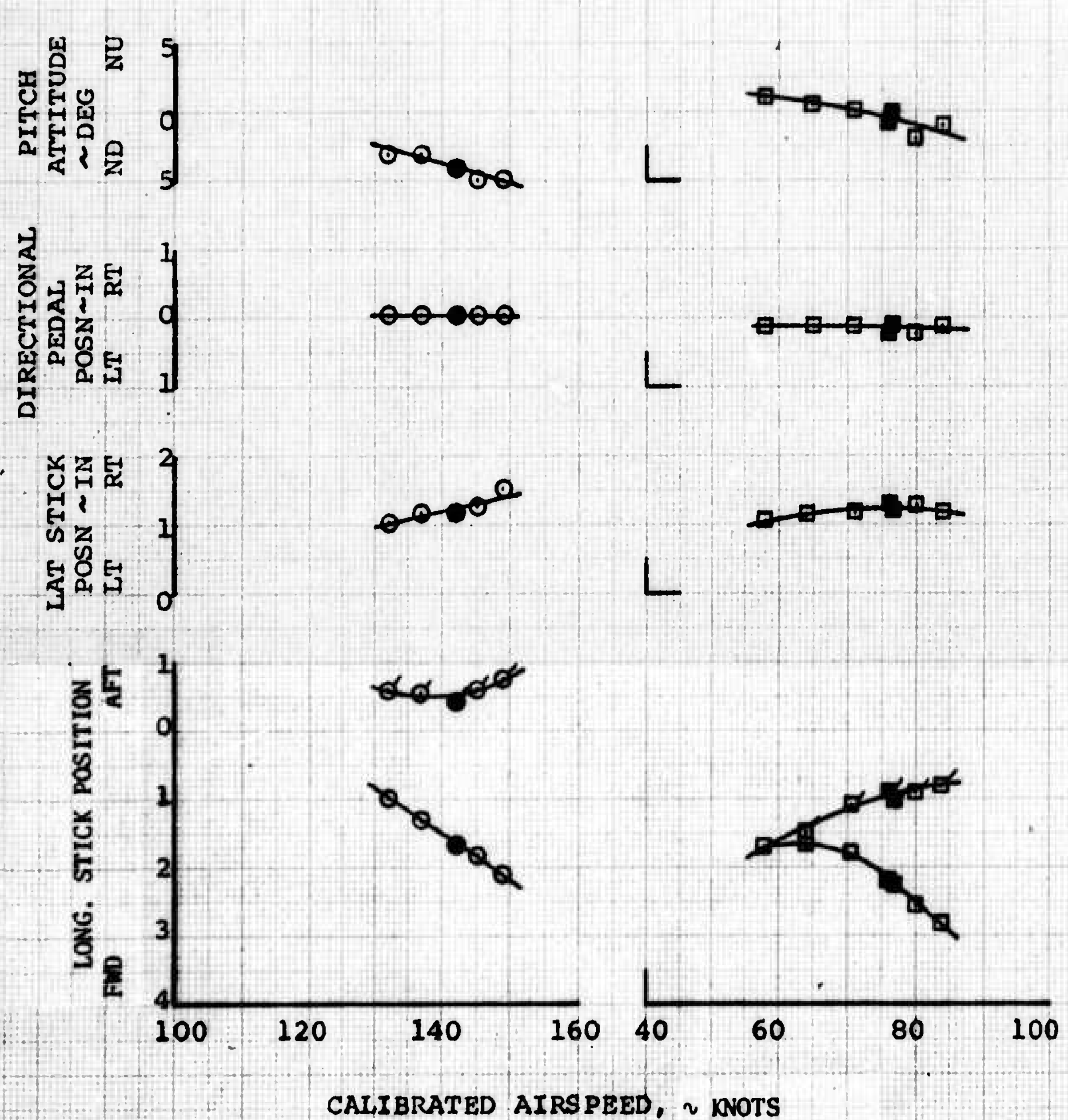


FIGURE 15
STATIC LONGITUDINAL COLLECTIVE-FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~ KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
⊡	152	Level	31980	237	-60	0.7 Aft	5.14
⊙	153	Level	32570	236	-100	1.0 Aft	5.18

Note:
1. Speed trim (DCP and Long Cyclic = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. PSA Configuration = ON
5. Tails denote - DCP off
6. Control travel shown in Apendix IV.

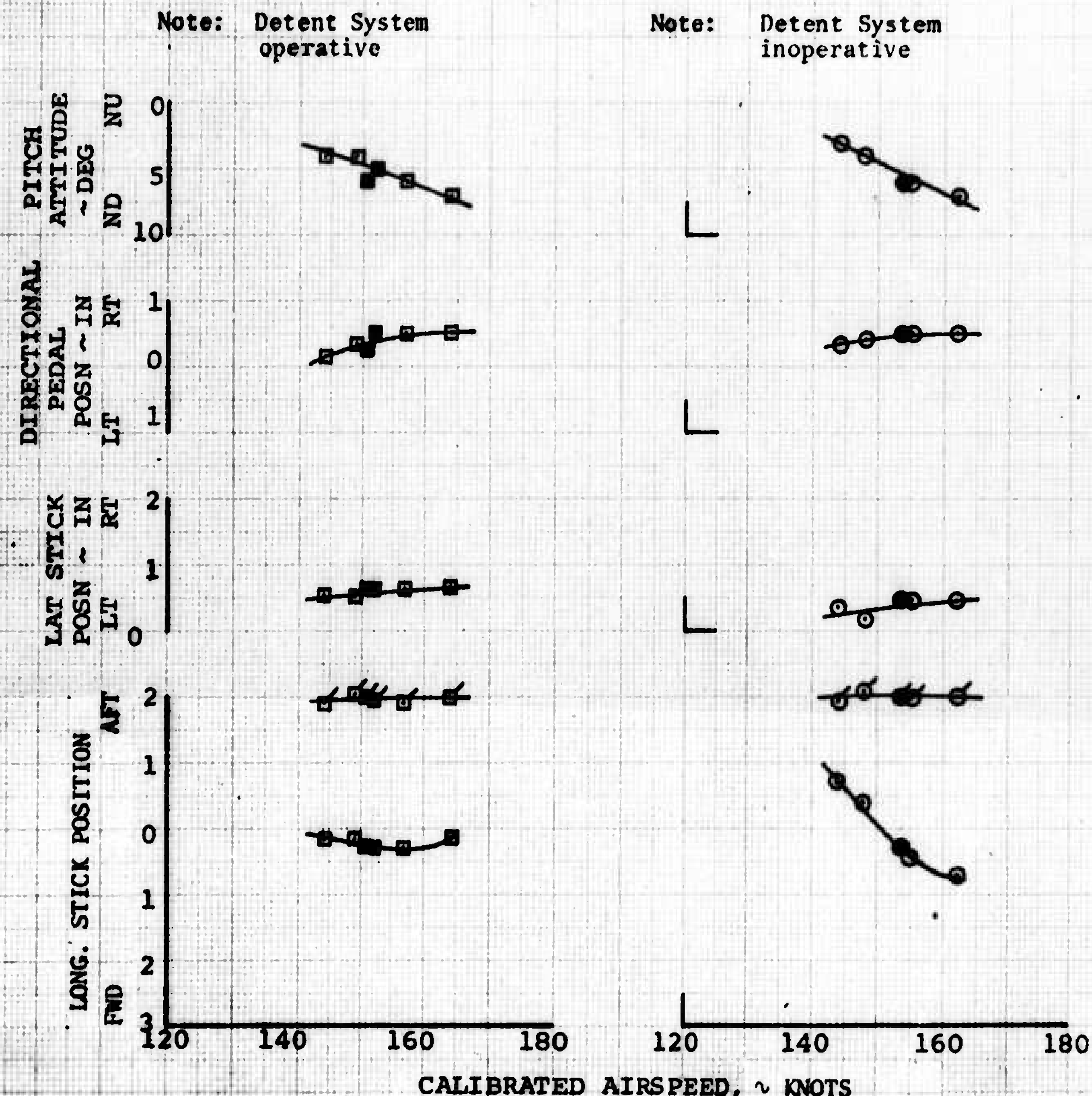


FIGURE 16
STATIC LONGITUDINAL COLLECTIVE-FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
◻	136	Level	29490	237	10000	1.7 Aft	5.91
○	136	Level	29220	236	9940	1.9 Aft	5.87

Note:
1. Speed trim (DCP and Long. Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. PSA Configuration = ON
5. Tails denote - DCP off
6. Control travel shown in Appendix IV.

Note: Detent System operative

Note: Detent System inoperative

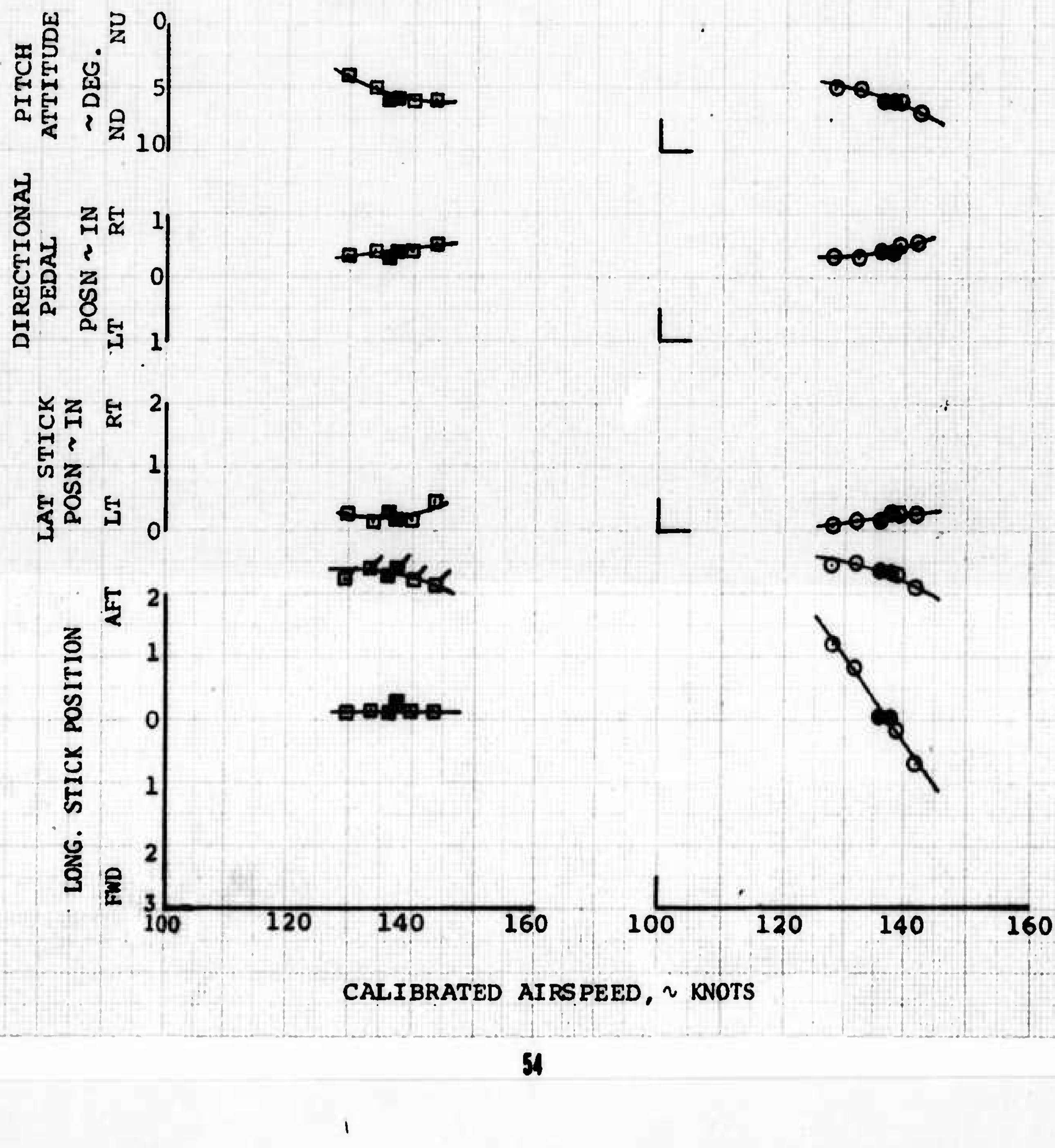


FIGURE 17
STATIC LONGITUDINAL COLLECTIVE-FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
◻	104 (V_{Cruise})	Level	28500	238	9520	2.4 Aft	3.99
○	104 (V_{Cruise}	Level	28260	238	9650	2.5 Aft	3.98

Note; 1. Speed Trim (DCP and Long. Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. PSA Configuration = ON
5. Tails denote - DCP off
6. Control travel shown in Appendix IV.

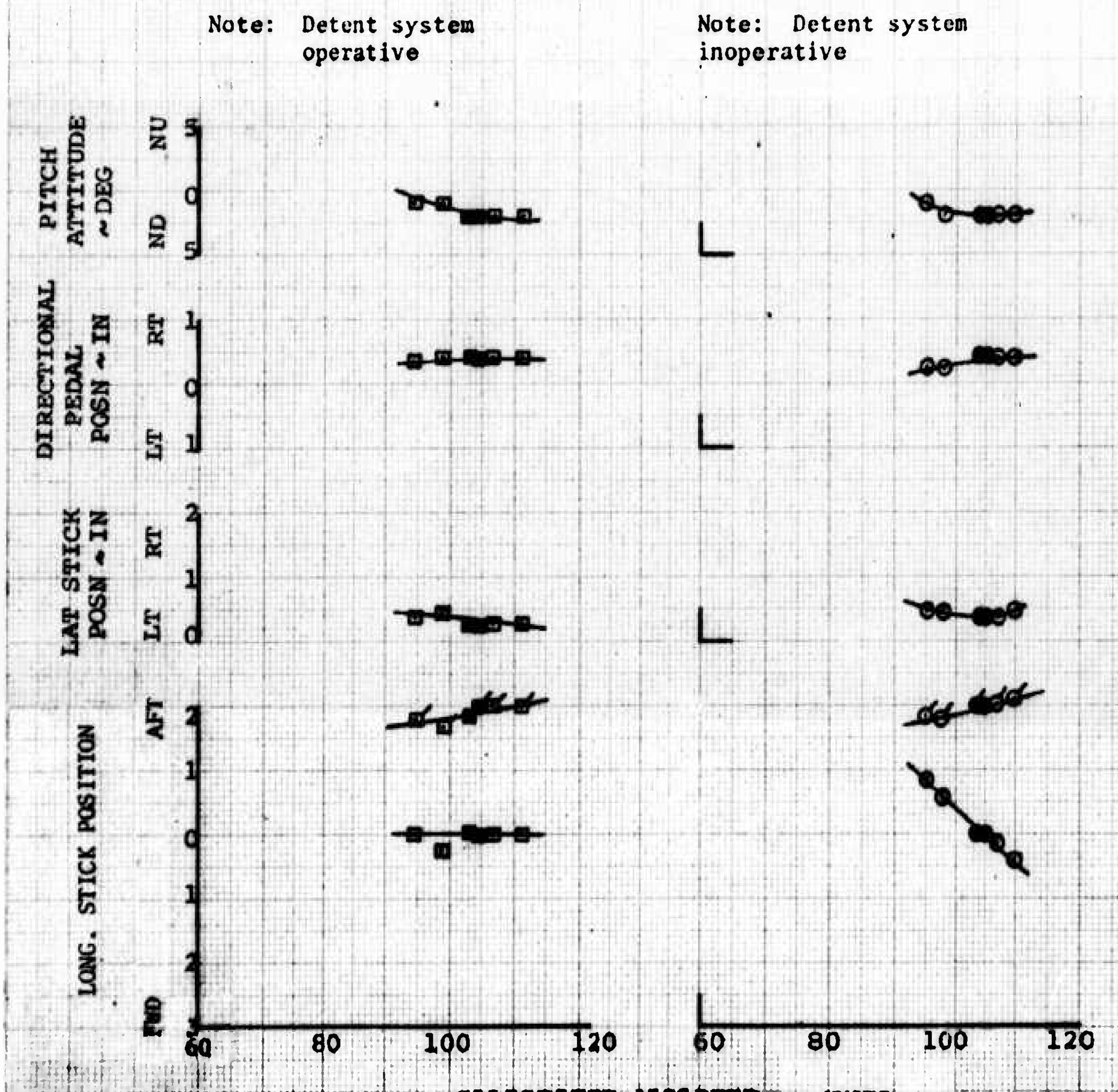


FIGURE 18
STATIC LONGITUDINAL COLLECTIVE-FIXED STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
⊡	59(V_{MinPwr})	Level	27940	238	9160	2.7 Aft	3.28
⊙	59(V_{MinPwr})	Level	27790	238	8820	2.8 Aft	3.29

Note: 1. Speed Trim (DCP and Long Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. PSA Configuration = ON
5. Tails denote - DCP off
6. Control travel shown in Appendix IV.

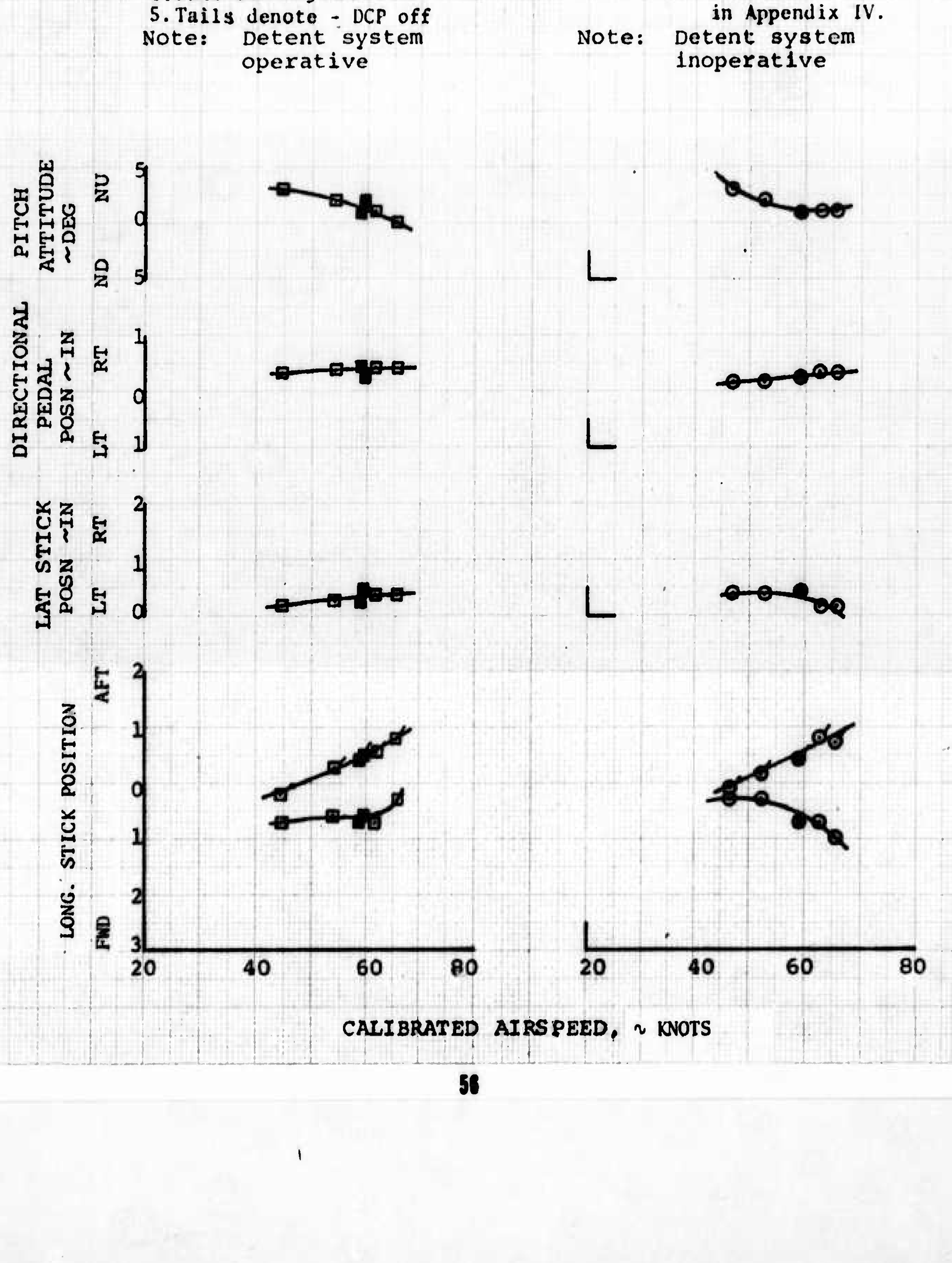


FIGURE 19
STATIC LATERAL DIRECTIONAL STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
⊙	107	Level	34760	237	9860	7.3 Aft	4.59
⊡	138	Level	33910	237	4680	7.6 Aft	4.87

Note:
1. Speed Trim (DCP and Long. Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system inoperative
5. PSA Configuration - ON
6. Tails denote ~ SAS OFF
7. Control travel shown in Appendix IV.

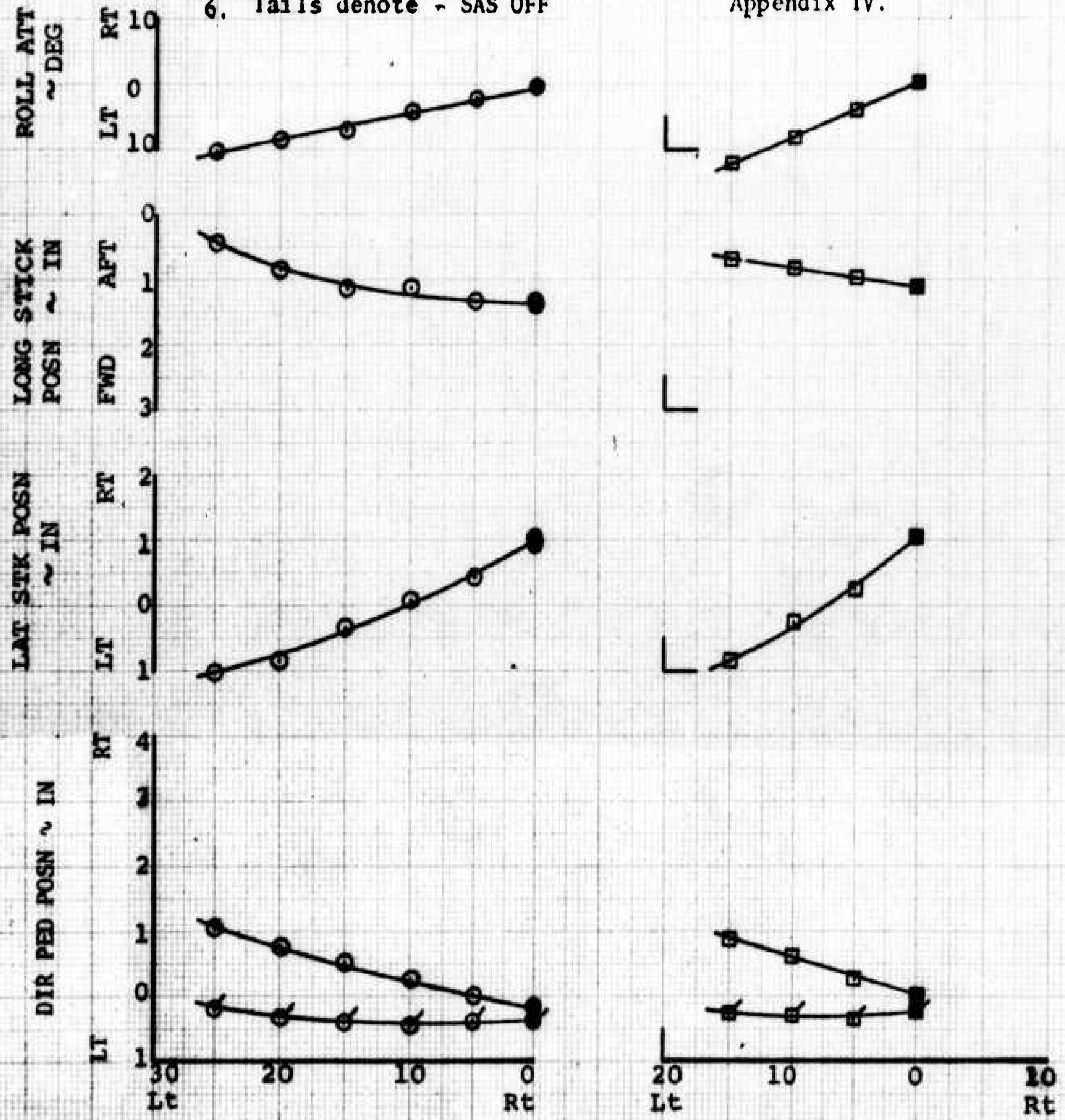


FIGURE 20
STATIC LATERAL DIRECTIONAL STABILITY
YCH-47C USA S/N 66-19121

SYM	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GW ~ LB	ROTOR SPEED ~ RPM	AVERAGE DENSITY ALT ~ FT	AVERAGE C.G. LOC ~ IN	COLL/PITCH POSN ~ IN
⊙	78	Level	45380	248	8150	4.2 Aft	4.40

Note:
1. Speed trim (DCP and Long. Cyclic) = Auto
2. SAS Configuration = ON
3. Shaded symbols denote trim points
4. Detent system inoperative
5. PSA Configuration = ON
6. Tails denote - SAS OFF
7. Control travel shown in Appendix IV.

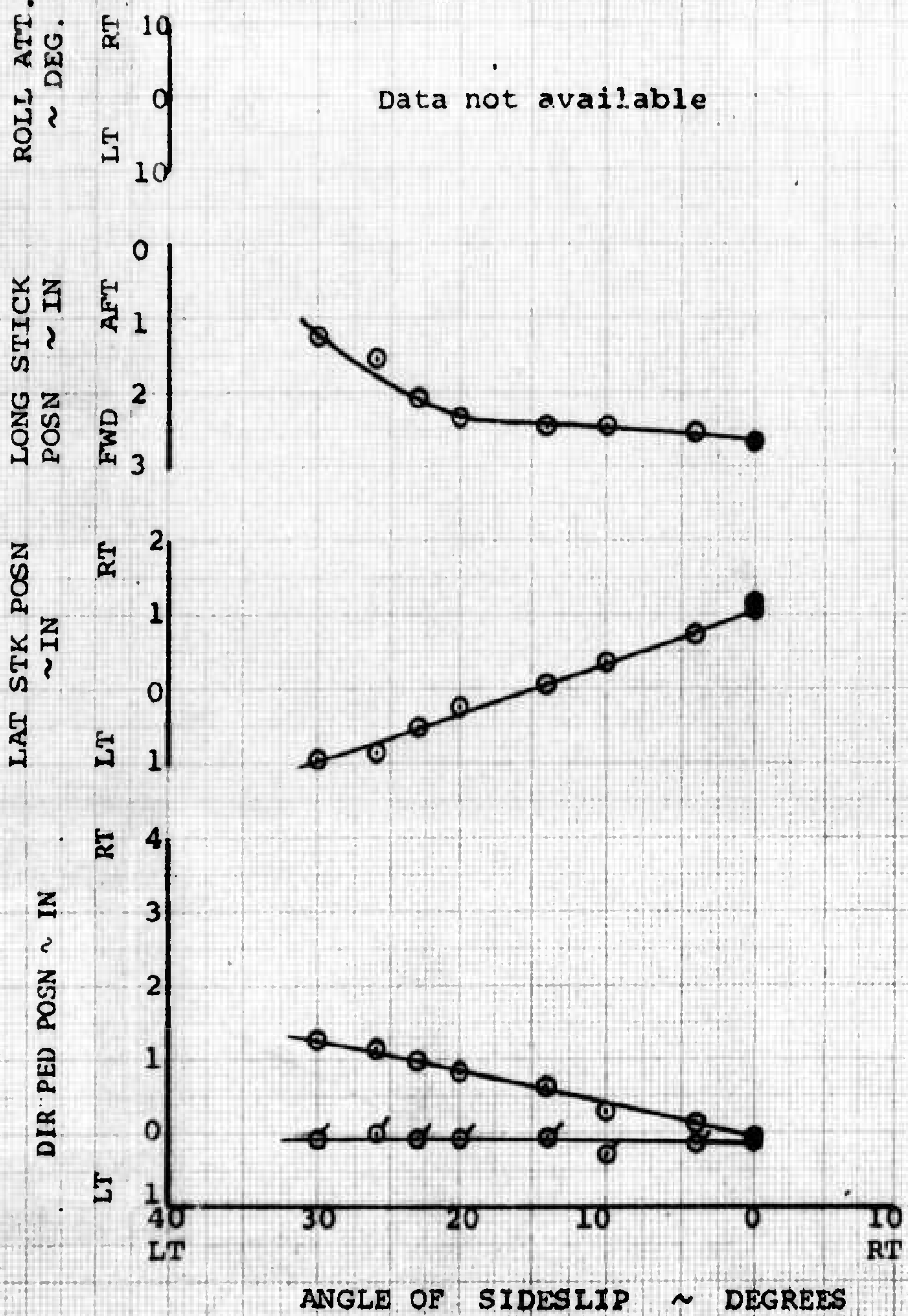


FIGURE 21
COMPARISON OF APE II AND III
STATIC LATERAL DIRECTIONAL STABILITY

TEST	TRIM SPEED ~KCAS	FLIGHT CONDITION	AVG GRWT ~ LB	ROTOR SPEED ~ RPM	AVG DENSITY ALTITUDE ~ FT	AVG CG ~IN.	REMARKS
APE III	138	LEVEL	33,910	237	4680	7.6 AFT	
APE II	136	LEVEL	36,480	234	4640	7.0	SAS ON

Note: Control travel shown in Appendix IV.

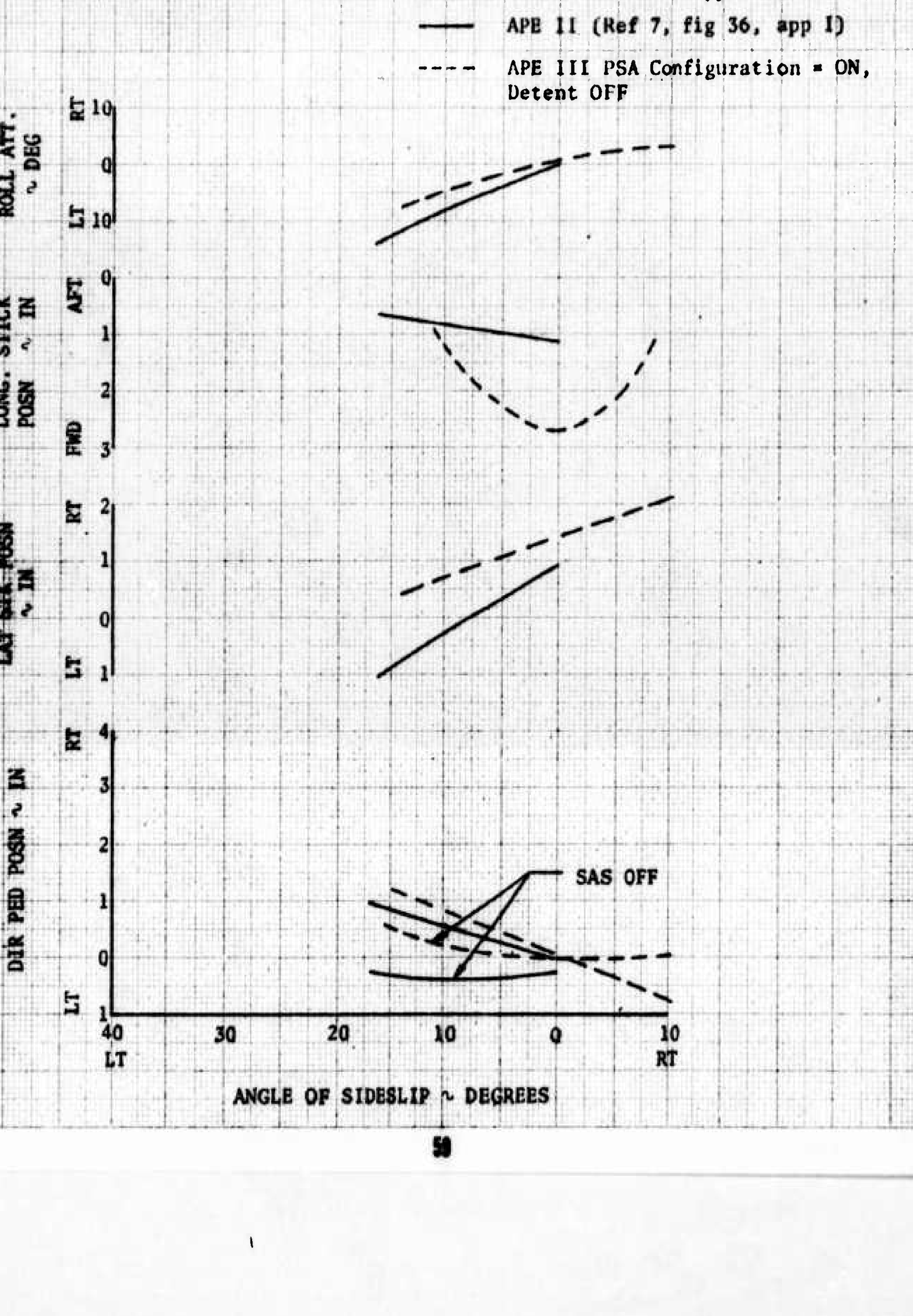


FIGURE 22.
LONGITUDINAL CONTROLLABILITY
YCH-47C USA S/N 66-19121
LEVEL FLIGHT

SYM	GROSS WEIGHT ~LB	DENSITY ALTITUDE ~FT	CAL. AIRSPEED ~KTS	C.G. LOC. ~IN.	ROTOR SPEED ~RPM	AVG. TIME TO MAX RATE~SEC	AVG. TIME TO MAX ACC.~SEC
⊙	45700	8270	69	3.9 AFT	246	.95	.50
⊡	42740	3920	85	5.3 AFT	247	.82	.51
▲	36550	13680	69	6.6 AFT	247	1.04	.60
◆	35700	13260	55	7.1 AFT	247	.90	.60

Note: 1. Speed trim (DCP and Long. Cyclic) = Auto
2. SAS Configuration = ON
3. Detent system = OFF
4. PSA Configuration = ON

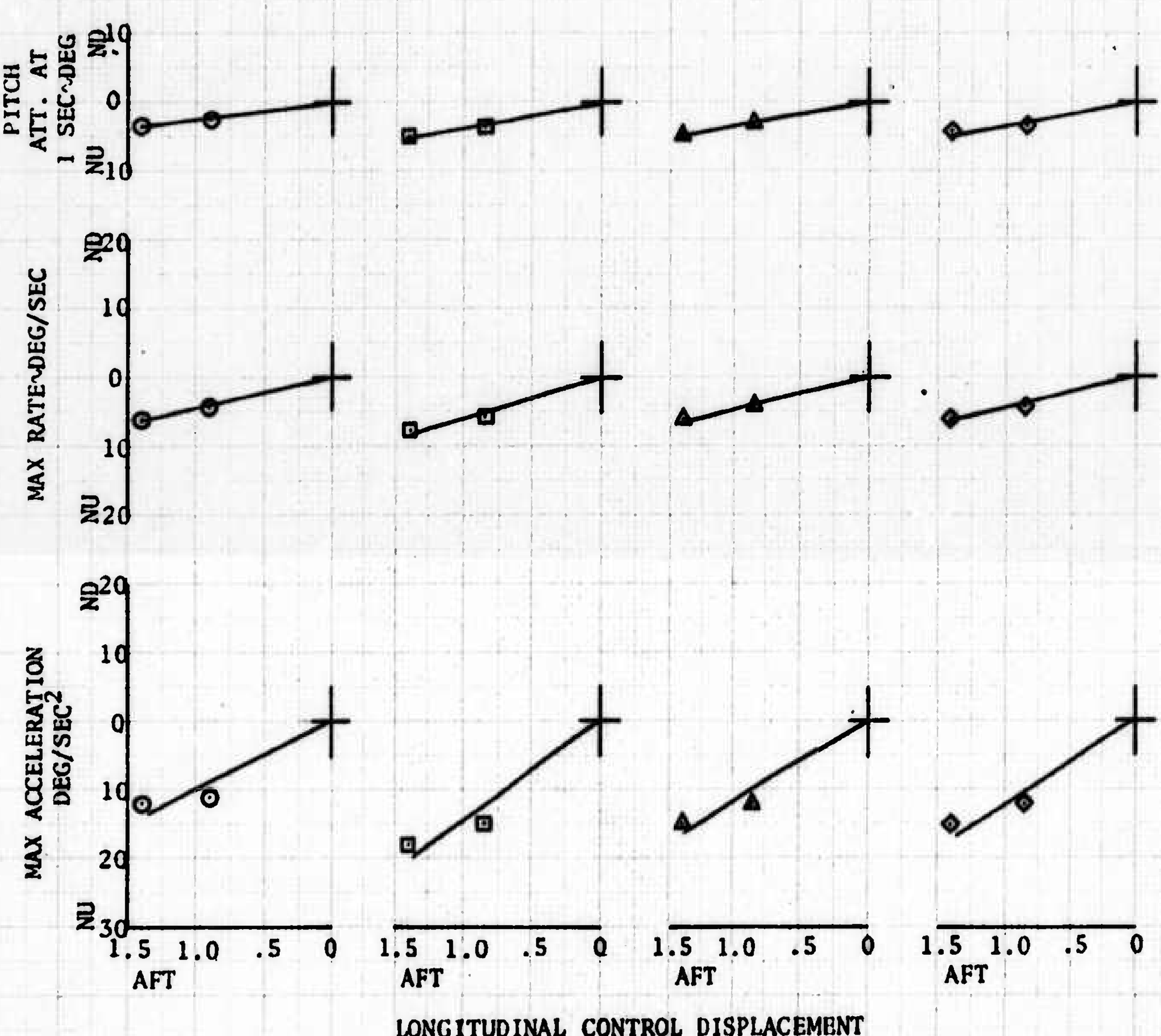


FIGURE 23
COMPARISON OF APE II AND APE III
LONGITUDINAL CONTROLLABILITY
IN LEVEL FLIGHT

TEST	GRWT ∿ LB	DENSITY ALTITUDE ∿ FT	AIRSPEED ∿ KCAS	C.G. ∿ IN.	SPEED ∿ RPM	AVERAGE TIME TO: MAX RATE ∿ SEC	AVERAGE TIME TO: MAX ACCEL ∿ SEC
APE III	36,550	13,680	69	6.6 AFT	247	1.04	0.60
APE II	36,120	13,120	70	7.0 AFT	245	1.0	0.25
APE III	45,700	8,270	69	3.9 AFT	246	0.95	0.50
APE II	44,795	7,770	71	5.0 AFT	243	0.90	0.30

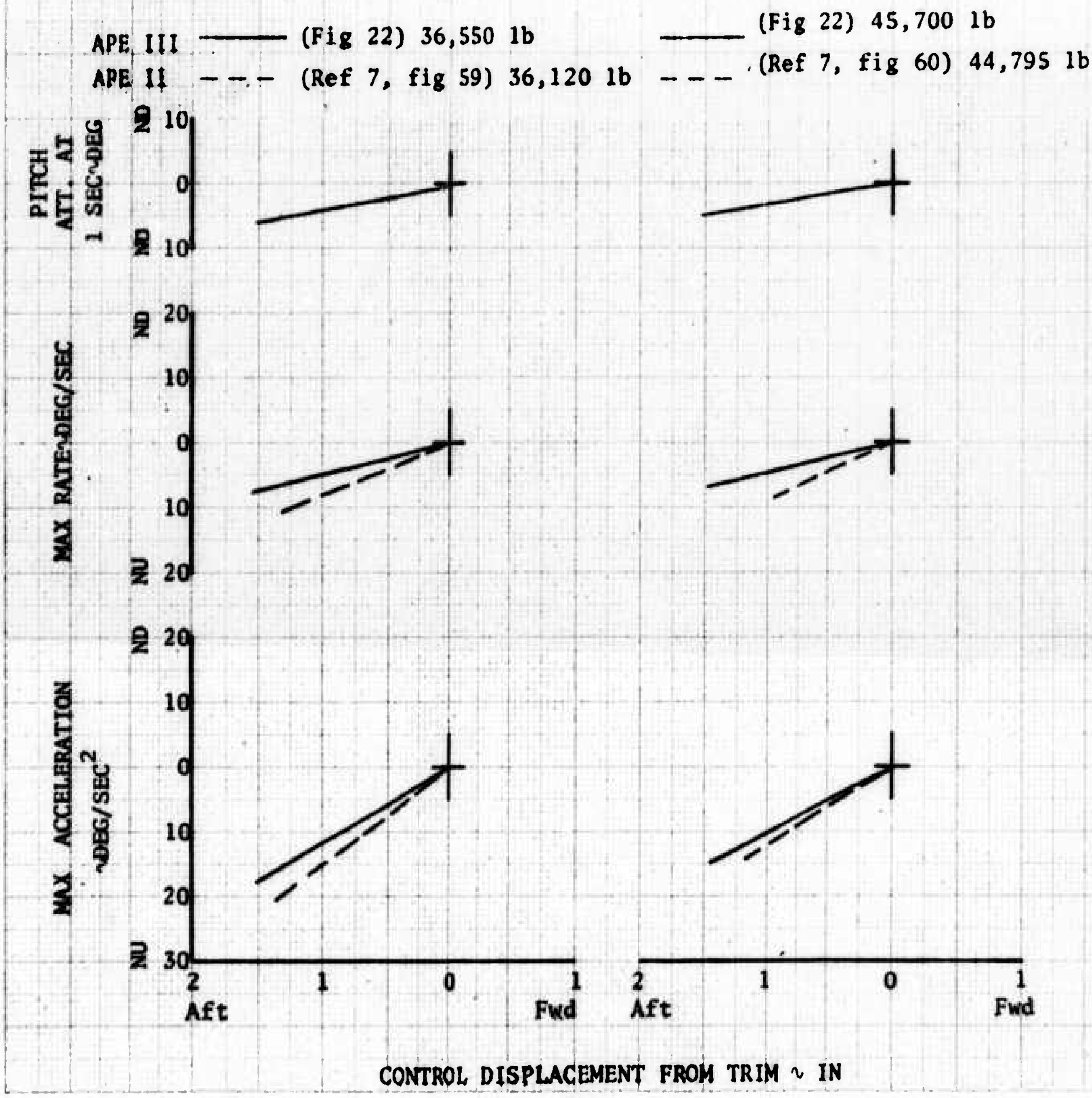


FIGURE 24
LATERAL CONTROLLABILITY
YCH-47C USA S/N 66-19121
LEVEL FLIGHT

SYM	GROSS WEIGHT ~LB	DENSITY ALTITUDE ~FT	CAL. AIRSPEED ~KTS	C.G. LOC. ~IN.	ROTOR SPEED ~RPM	AVG. TIME TO MAX RATE ~SEC	AVG. TIME TO MAX ACC. ~SEC
○	42650	4000	84	5.3 AFT	246	.61	.53
□	30980	-40	156	2.2 AFT	236	.82	.61
△	30680	-20	128	2.4 AFT	237	.75	.69
◇	30380	-20	75	2.6 AFT	237	.76	.62

Note: 1. Speed trim (DCP and Long. Cyclic) = ON
2. SAS Configuration = ON
3. Detent system = OFF
4. PSA Configuration = ON

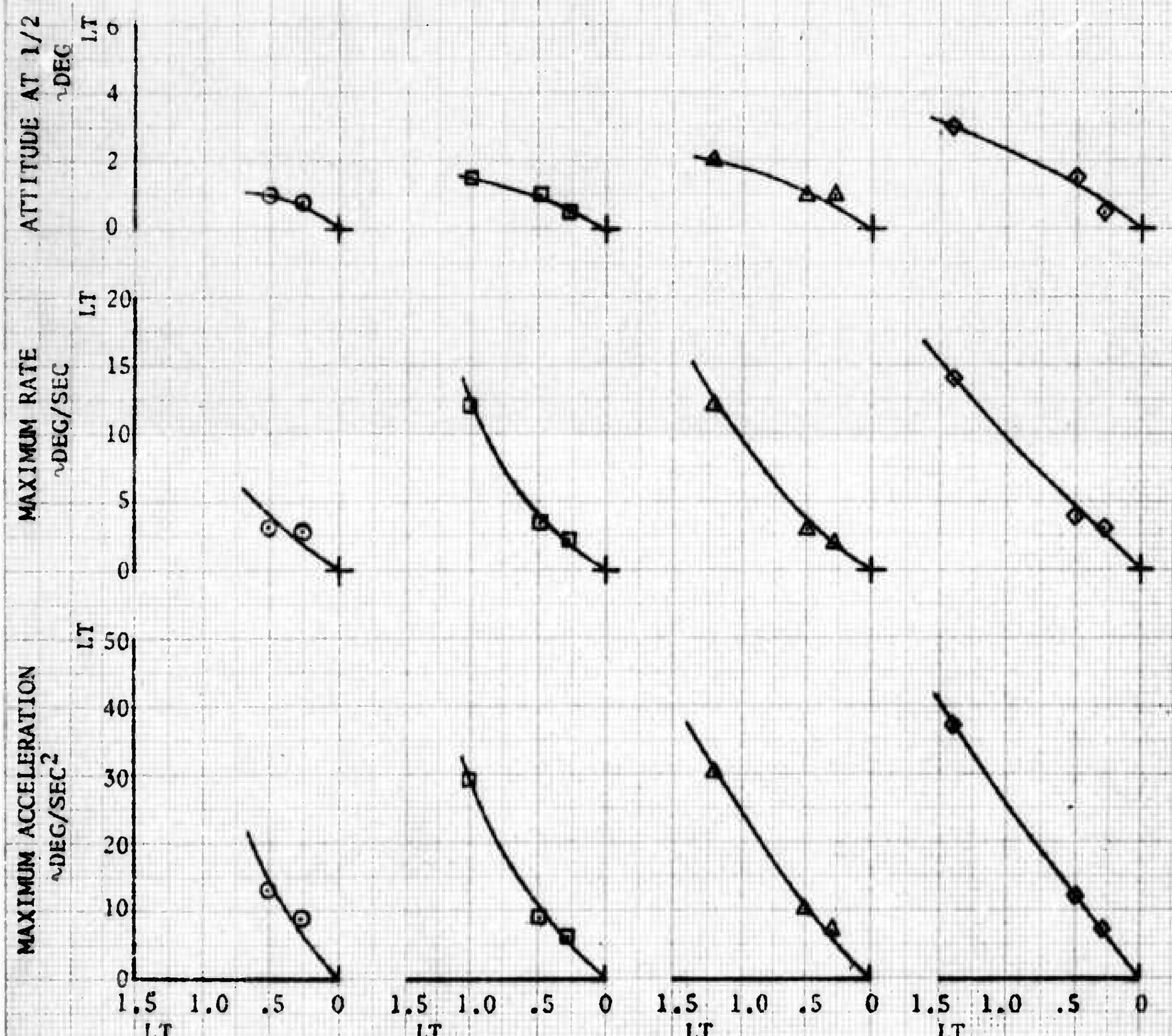


FIGURE 25
COMPARISON OF APE II AND APE III
LATERAL CONTROLLABILITY
IN LEVEL FLIGHT

TEST	GRWT ~ LB	DENSITY ALTITUDE ~ FT	AIRSPEED ~ KCAS	C.G. ~IN.	SPEED ~ RPM	AVERAGE TIME TO: MAX RATE ~SEC	MAX ACCEL ~ SEC.
APE III	42,650	4000	84	5.3 AFT	246	0.61	0.53
APE II	46,440	4770	76	4.0 AFT	244	0.55	0.25

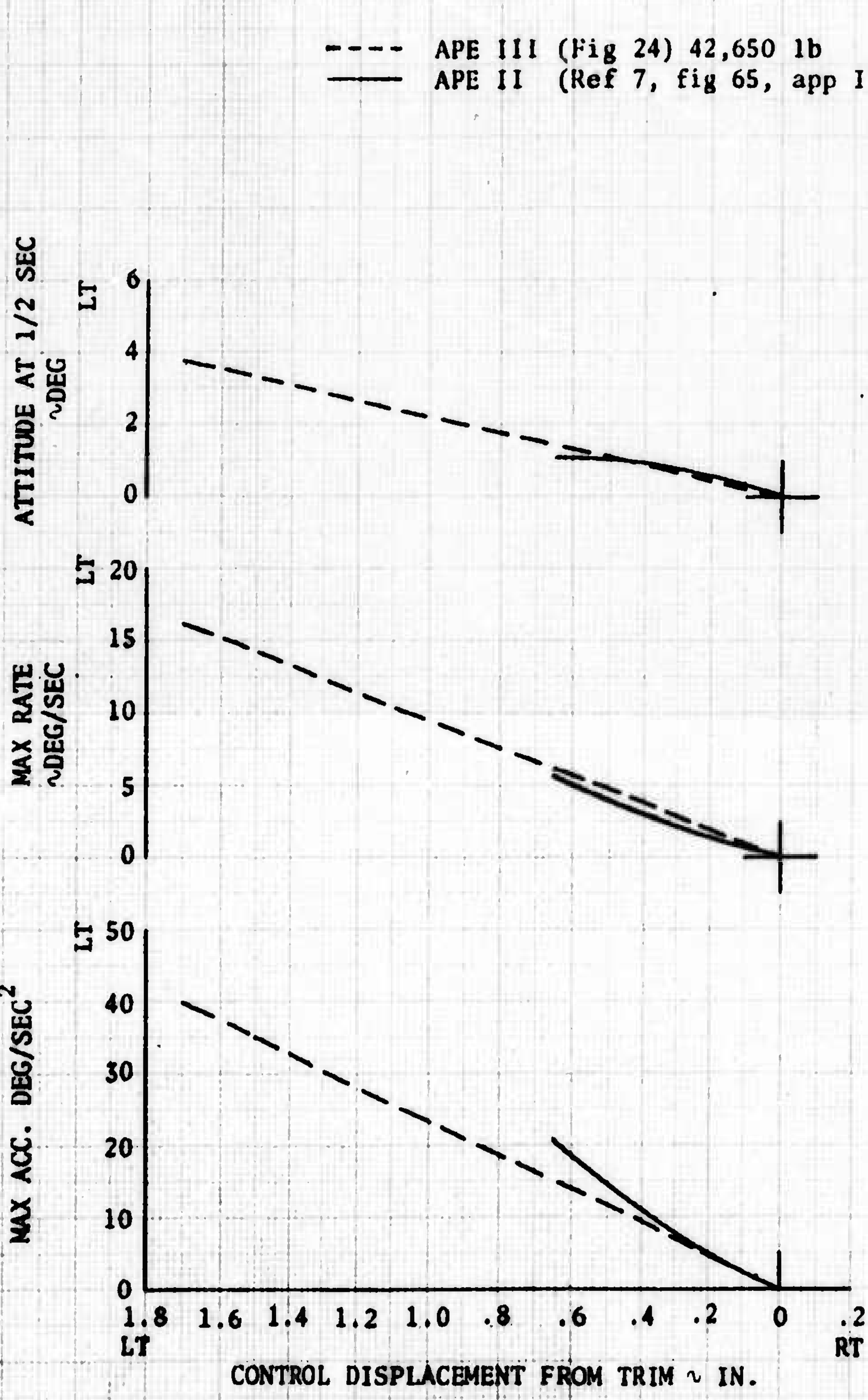
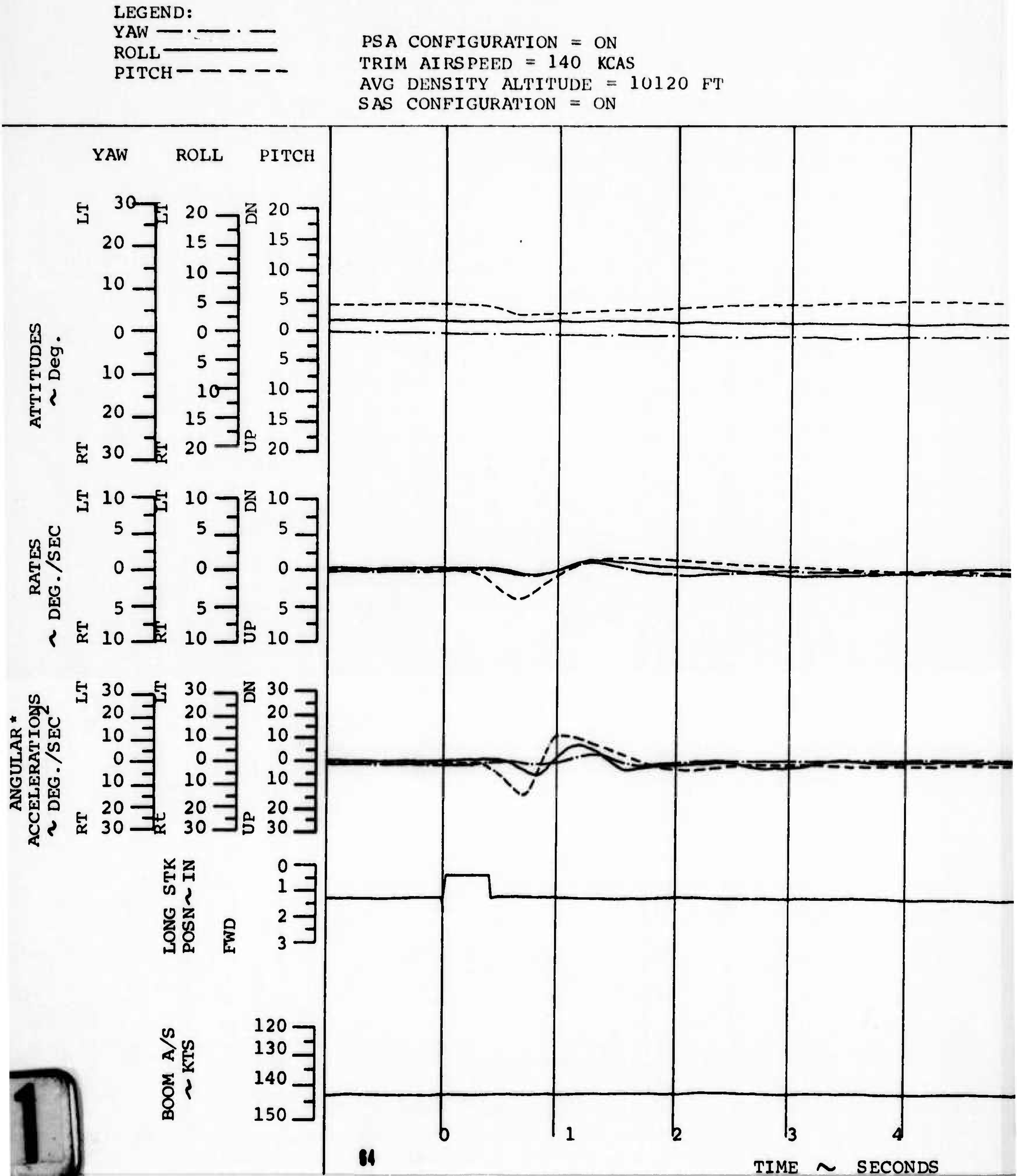


FIGURE 26
AFT LONGITUDINAL PULSE
YCH-47C USA S/N 66-19121



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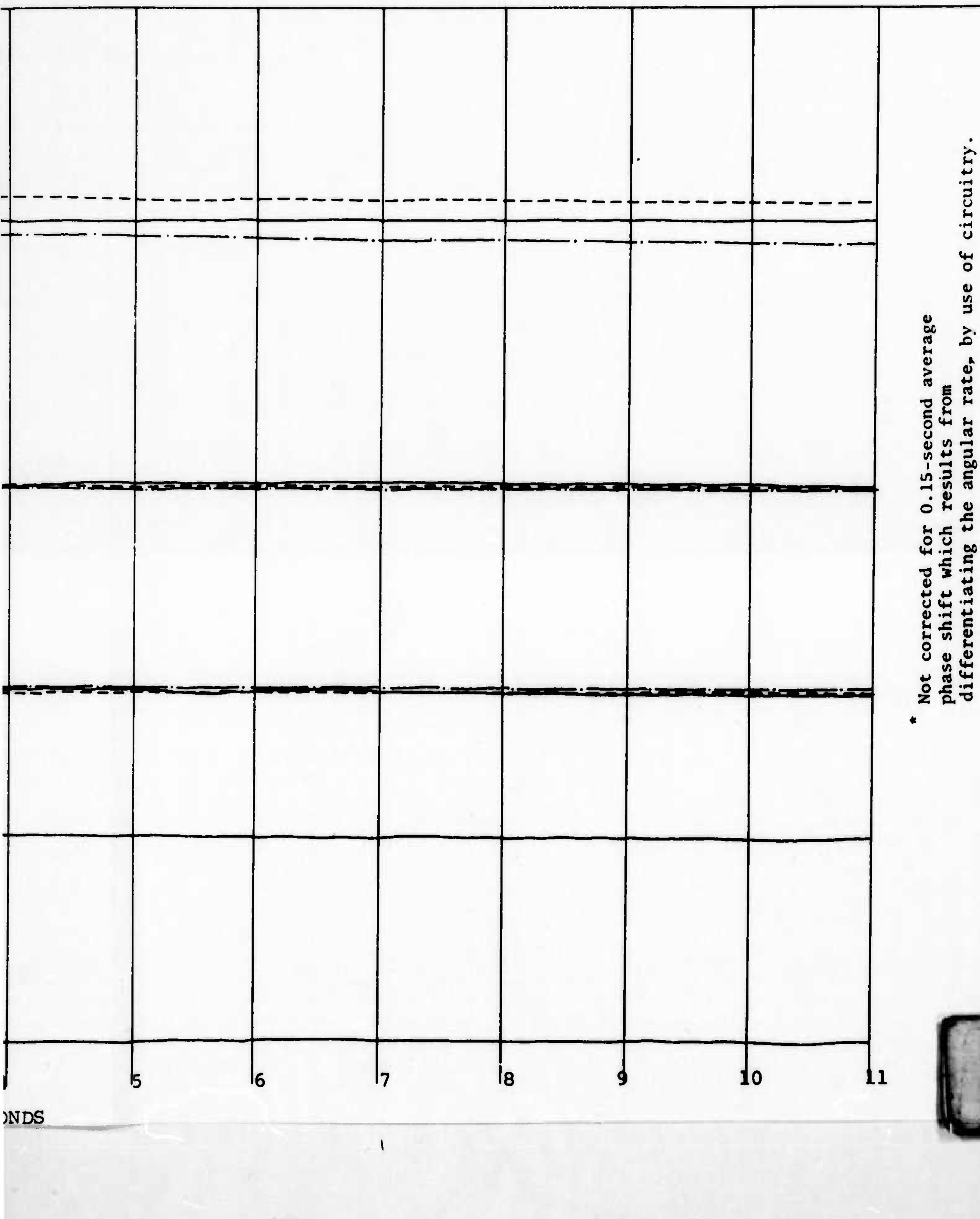
AVG. GROSS WEIGHT = 29070 LB
AVG. ROTOR SPEED = 236 RPM
C.G. LOCATION = 3.7 IN AFT
SPEED TRIM (LONG CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO



* Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE 2
AFT LONGITUDINA
YCH-47C USA S/N

LEGEND:
YAW — · — · —
ROLL ————
PITCH – – – –

PSA CONFIGURATION = ON
TRIM AIRSPEED = 69 KCAS
AVG. DENSITY ALTITUDE = 7750 FT
SAS CONFIGURATION = ON

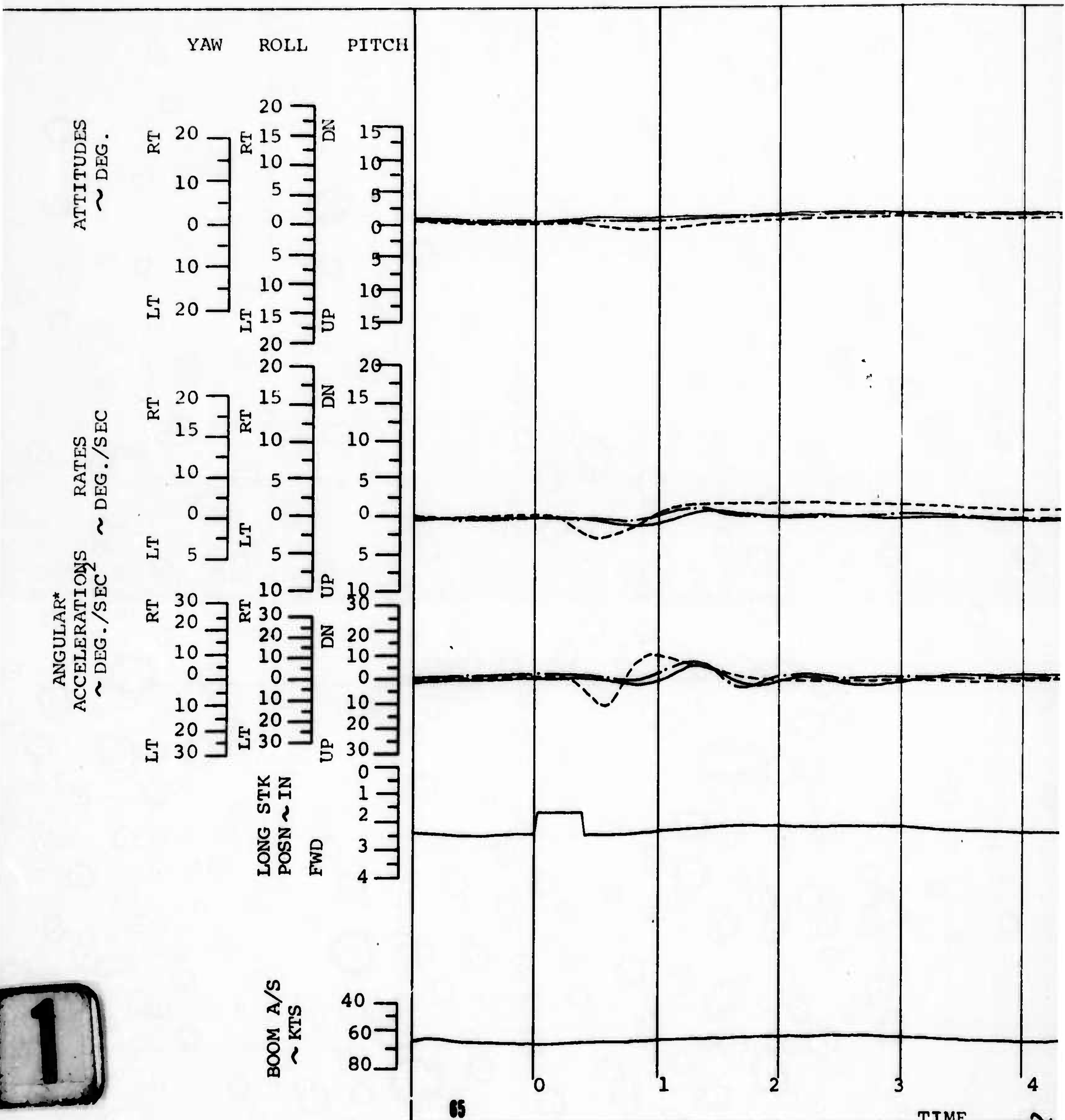
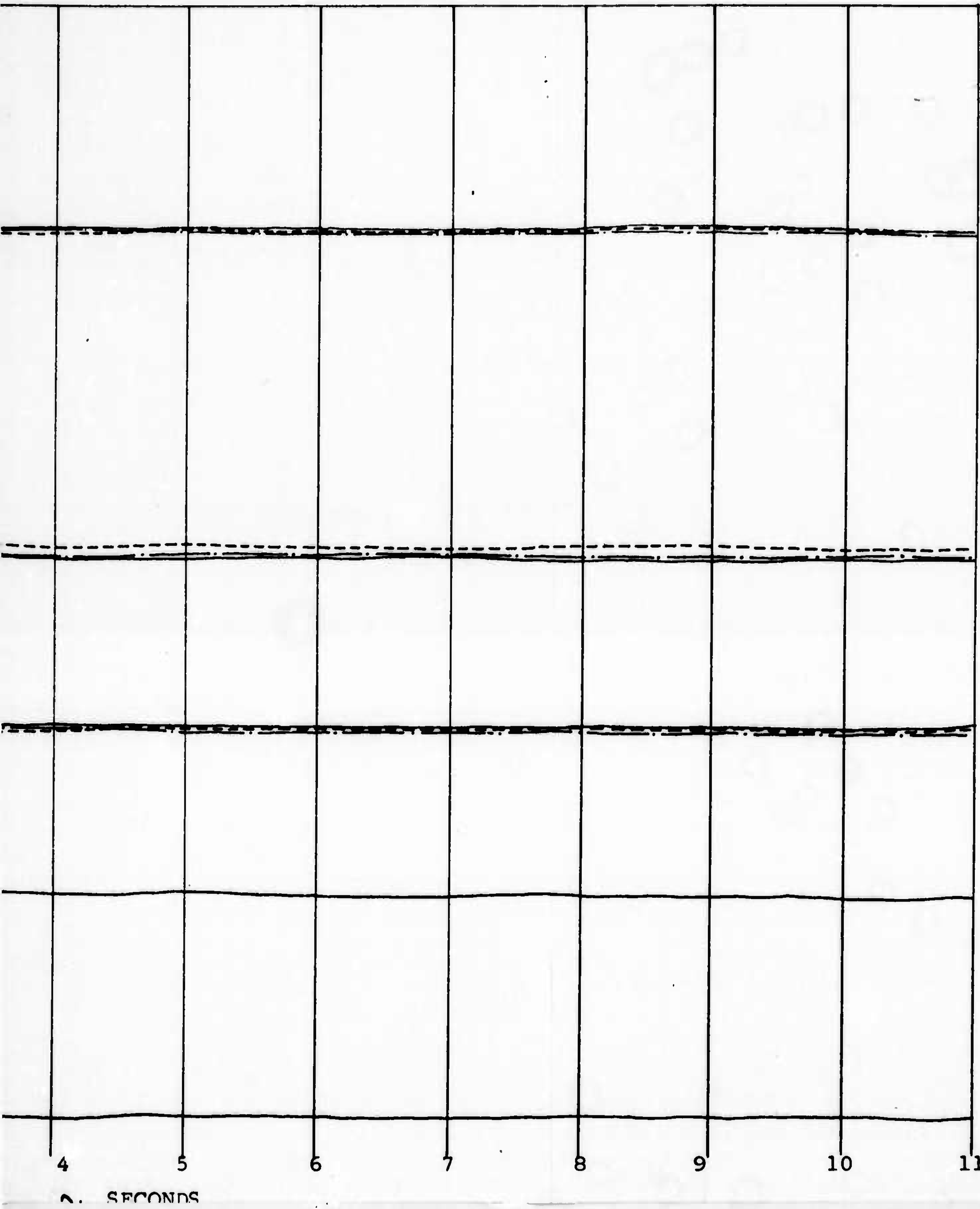


FIGURE 27
NGITUDINAL PULSE
USA S/N 66-19121

AVG. GROSS WEIGHT = 45500 LB
AVG. ROTOR SPEED = 247 RPM
C.G. LOCATION = 4.0 IN AFT
SPEED TRIM (LONG CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO

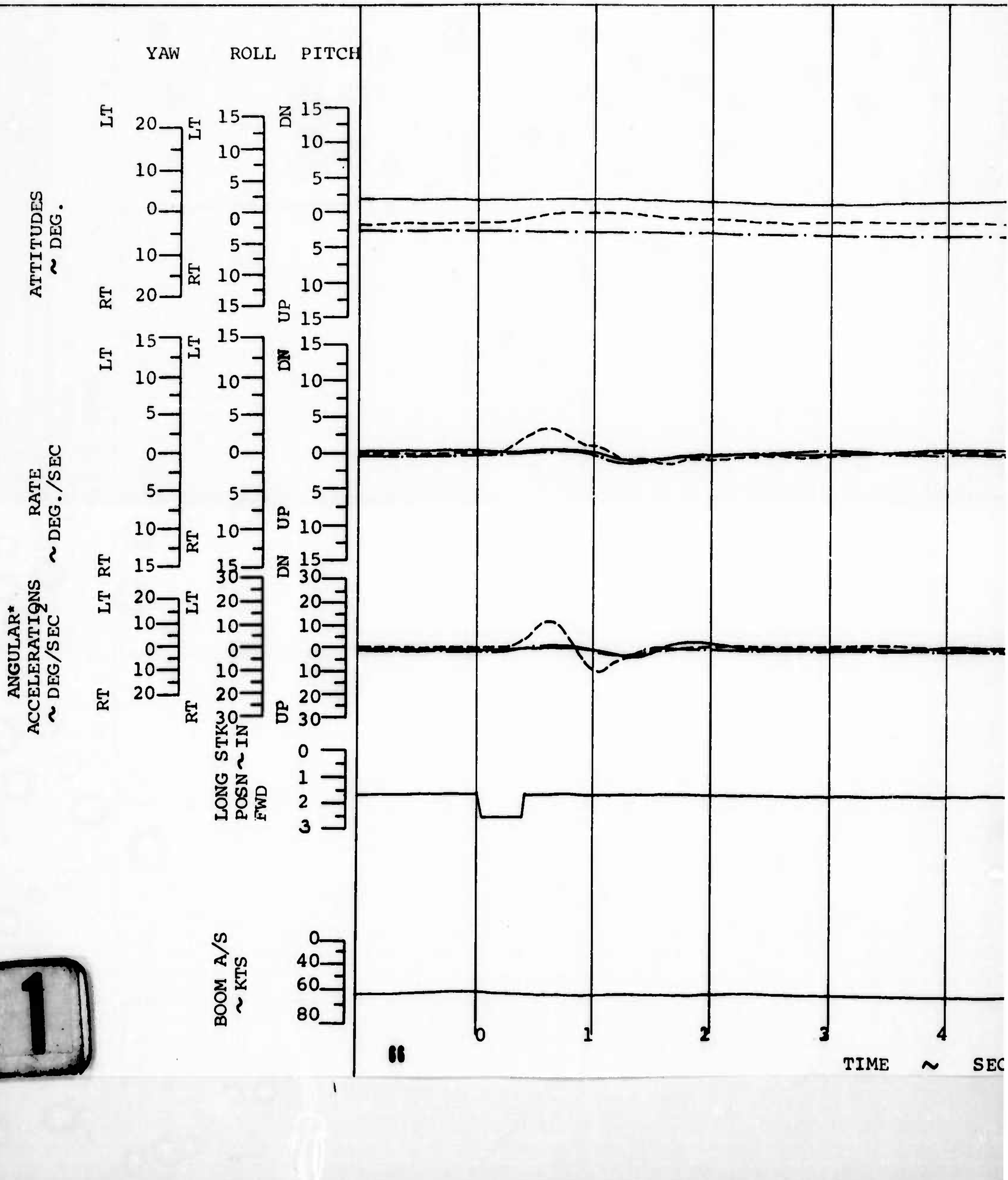


* Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE 28
FORWARD LONGITUDIN
YCH-47C USA S/N

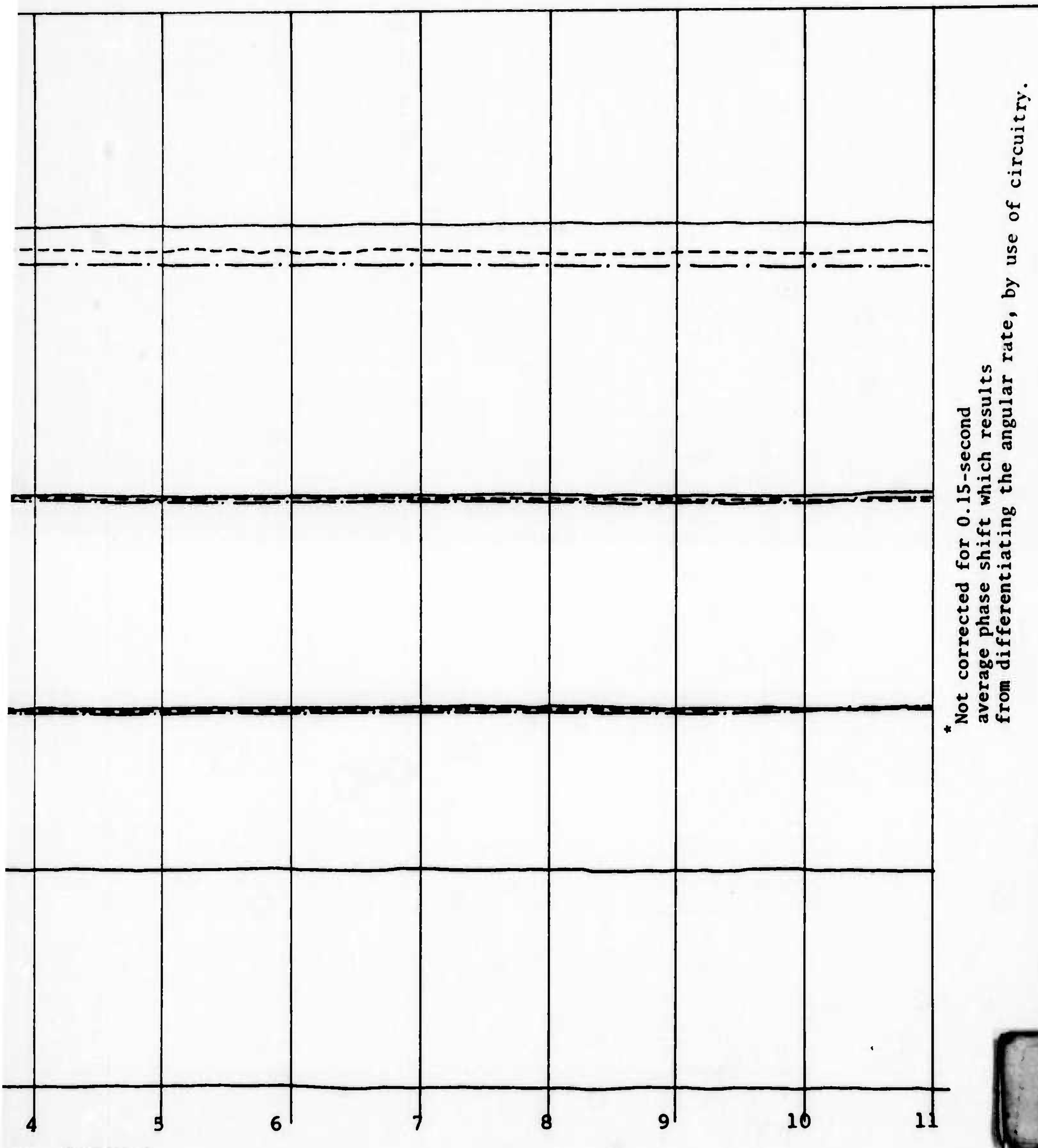
LEGEND:
YAW —·—·—
ROLL————
PITCH- - - - -

PSA CONFIGURATION = ON
TRIM AIRSPEED = 71 KCAS
AVG. DENSITY ALTITUDE = 13500 FT
SAS CONFIGURATION = ON



GURE 28
GITUDINAL PULSE
USA S/N 66-19121

AVG. GROSS WEIGHT = 36760 LB
AVG. ROTOR SPEED = 246 RPM
C.G. LOCATION = 6.3 IN AFT
SPEED TRIM (LONG. CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO

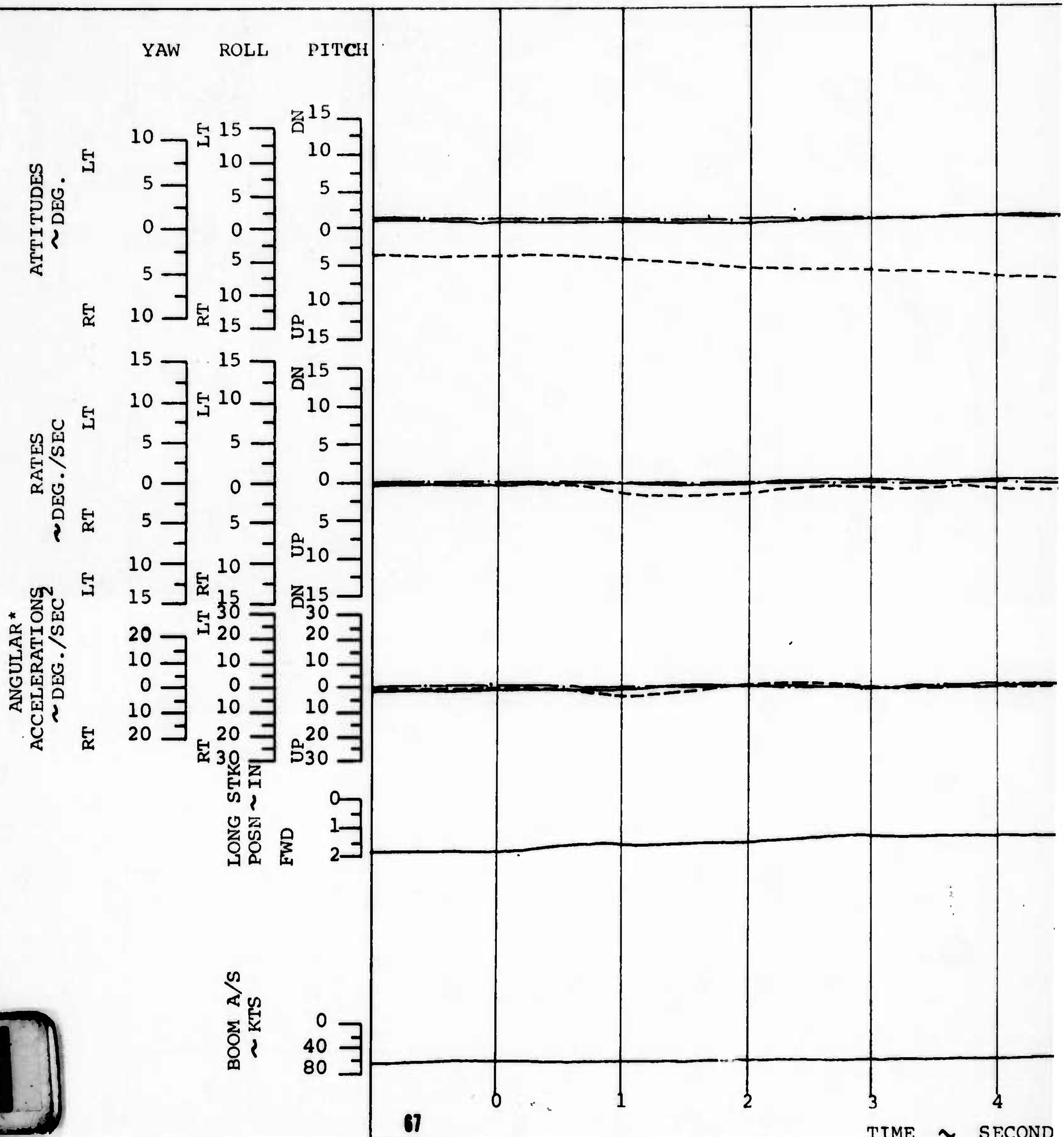


*Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE 29
5 KNOT DECELERA
YCH-47C USA S/N 6

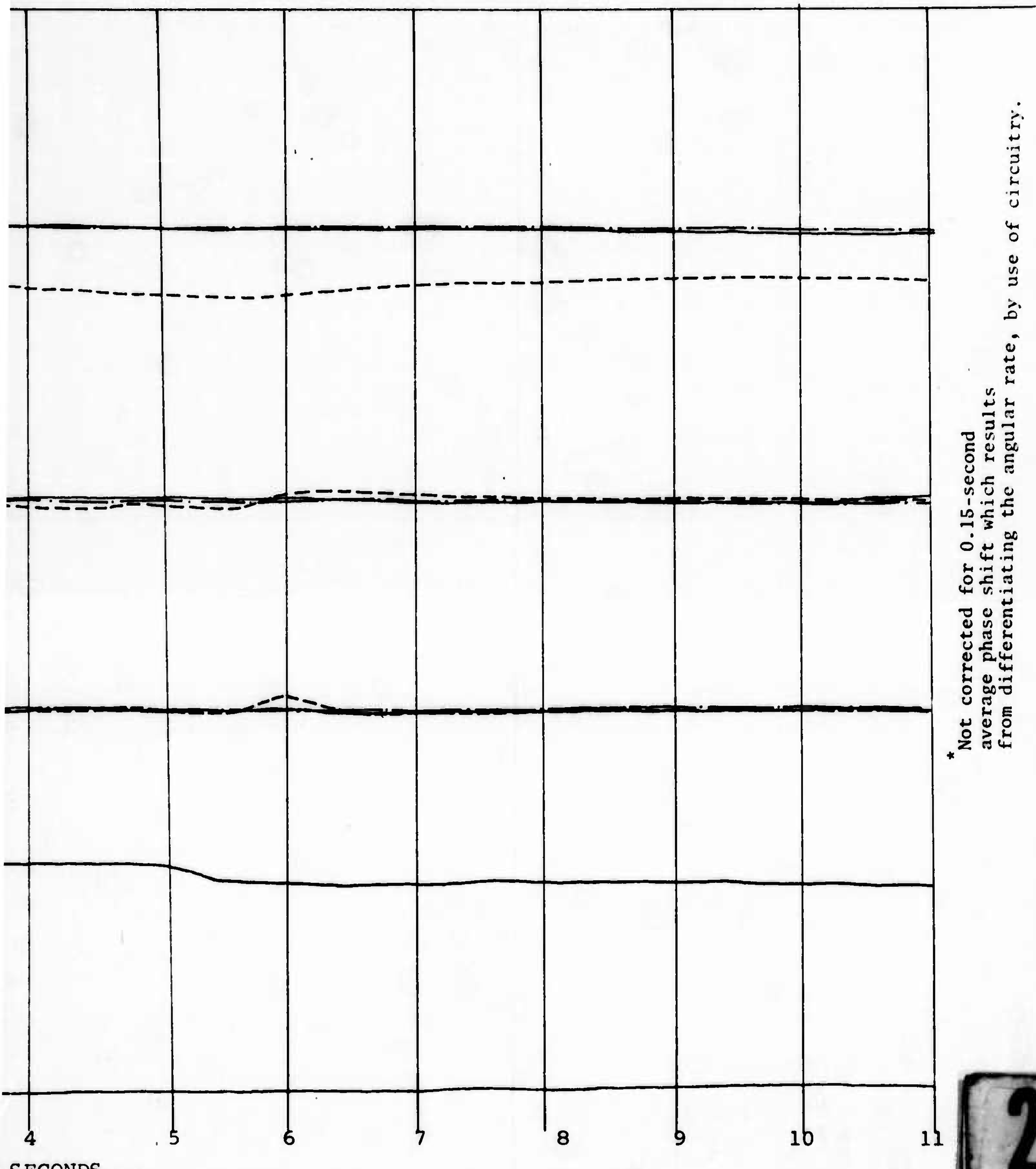
LEGEND:
YAW — · — · —
PITCH - - - - - -
ROLL ————

PSA CONFIGURATION = ON
TRIM AIRSPEED = 55 KCAS
AVG. DENSITY ALTITUDE = 13495 FT
SAS CONFIGURATION = ON



GURE 29
DECELERATION
SA S/N 66-19121

AVG. GROSS WEIGHT = 35800 LB
AVG. ROTOR SPEED = 247 RPM
C.G. LOCATION = 7.0 IN AFT
SPEED TRIM (LONG. CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO

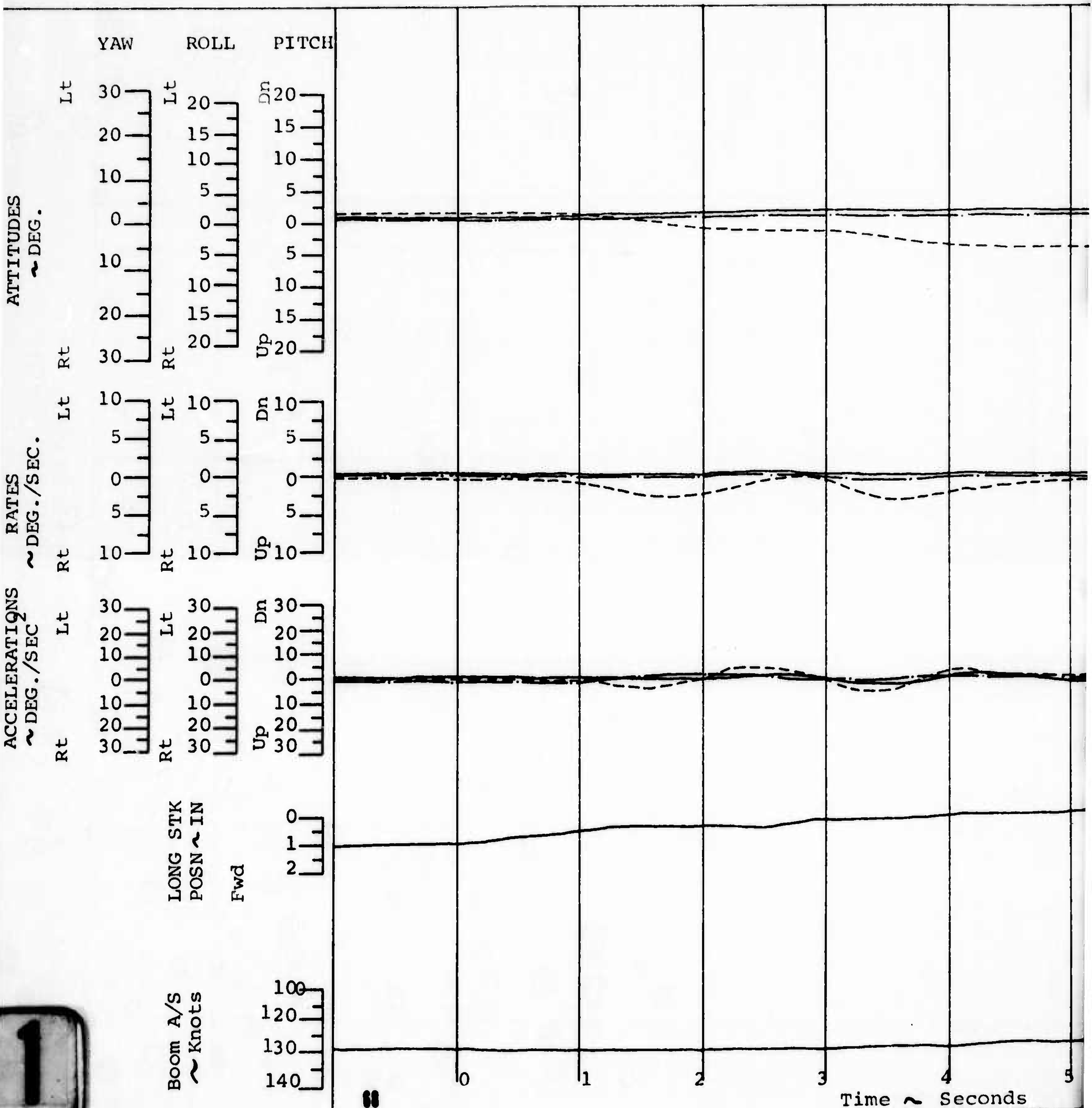


*Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE 30
10 KNOT DECELERATION
YCH-47C USA S/N 66-19121

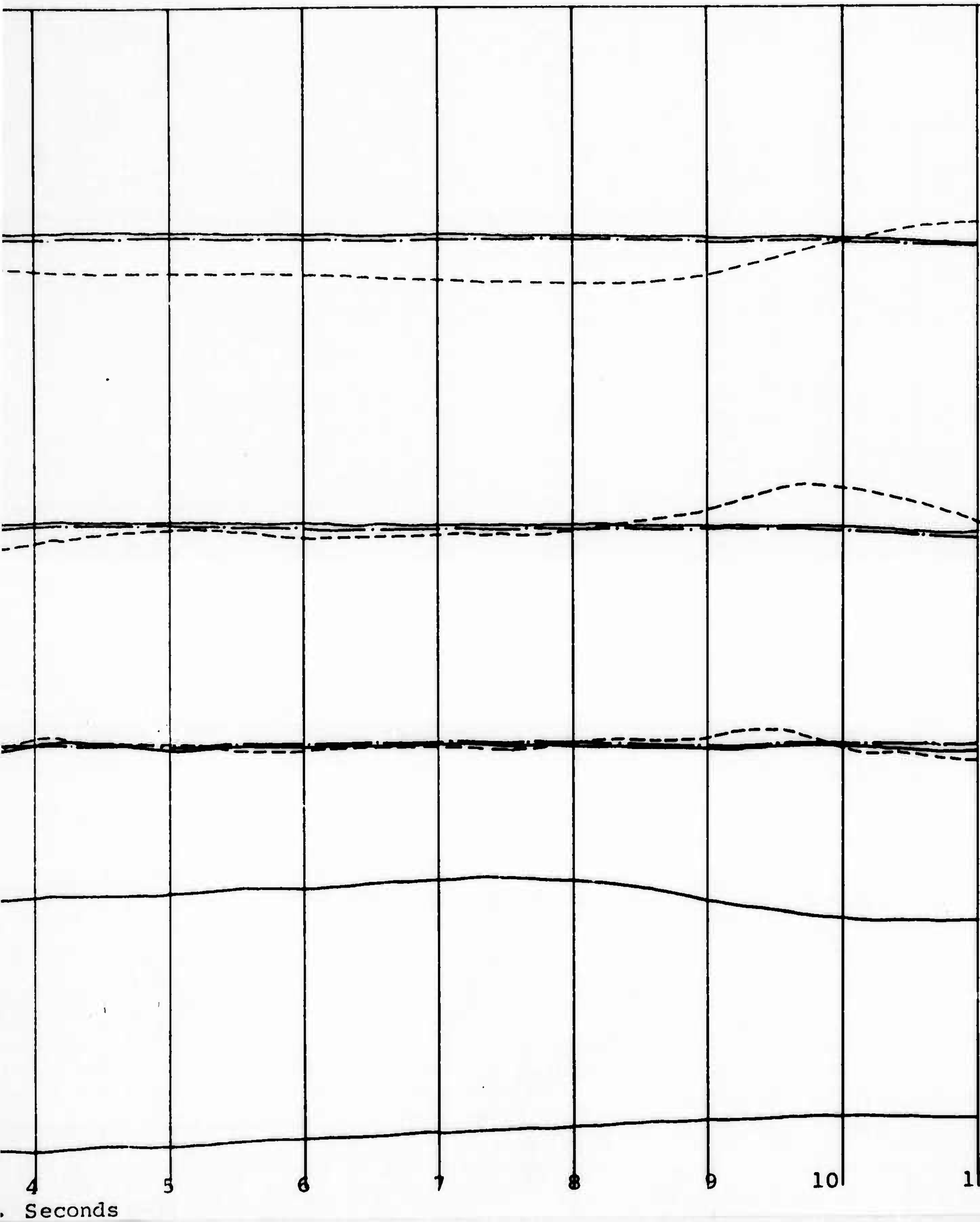
LEGEND:
YAW — · — · —
ROLL ————
PITCH - - - - -

PSA CONFIGURATION = ON
TRIM AIRSPEED = 128 KCAS
AVG DENSITY ALTITUDE = 30 FT
SAS CONFIGURATION = ON

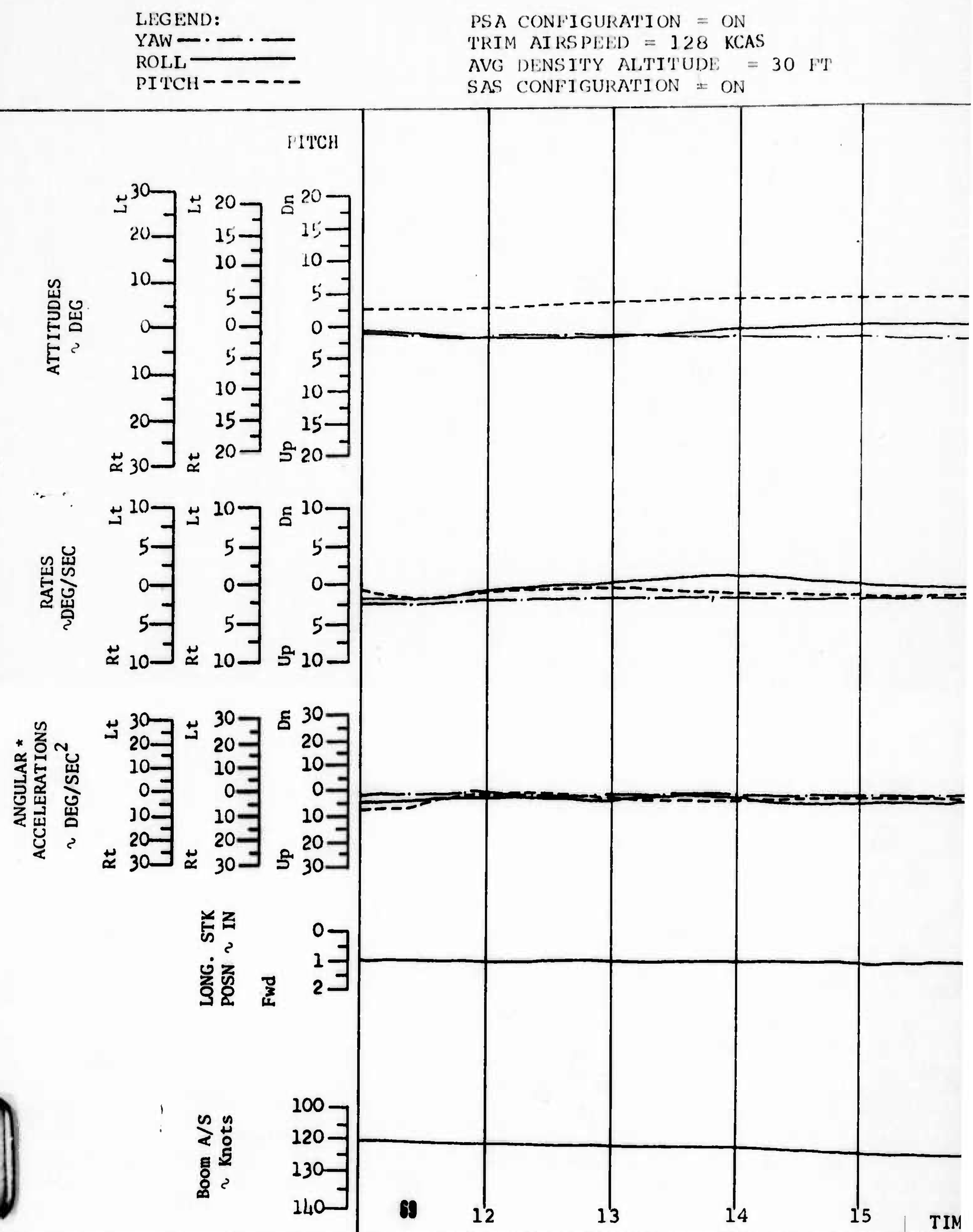


30
LERATION
/N 66-19121

AVG GROSS WEIGHT = 30670 Lb
AVG ROTOR SPEED = 237 RPM
C. G. LOCATION = 2.4 In.Aft
SPEED TRIM (LONG CYCLIC) = Auto
SPEED TRIM (DCP) = Auto

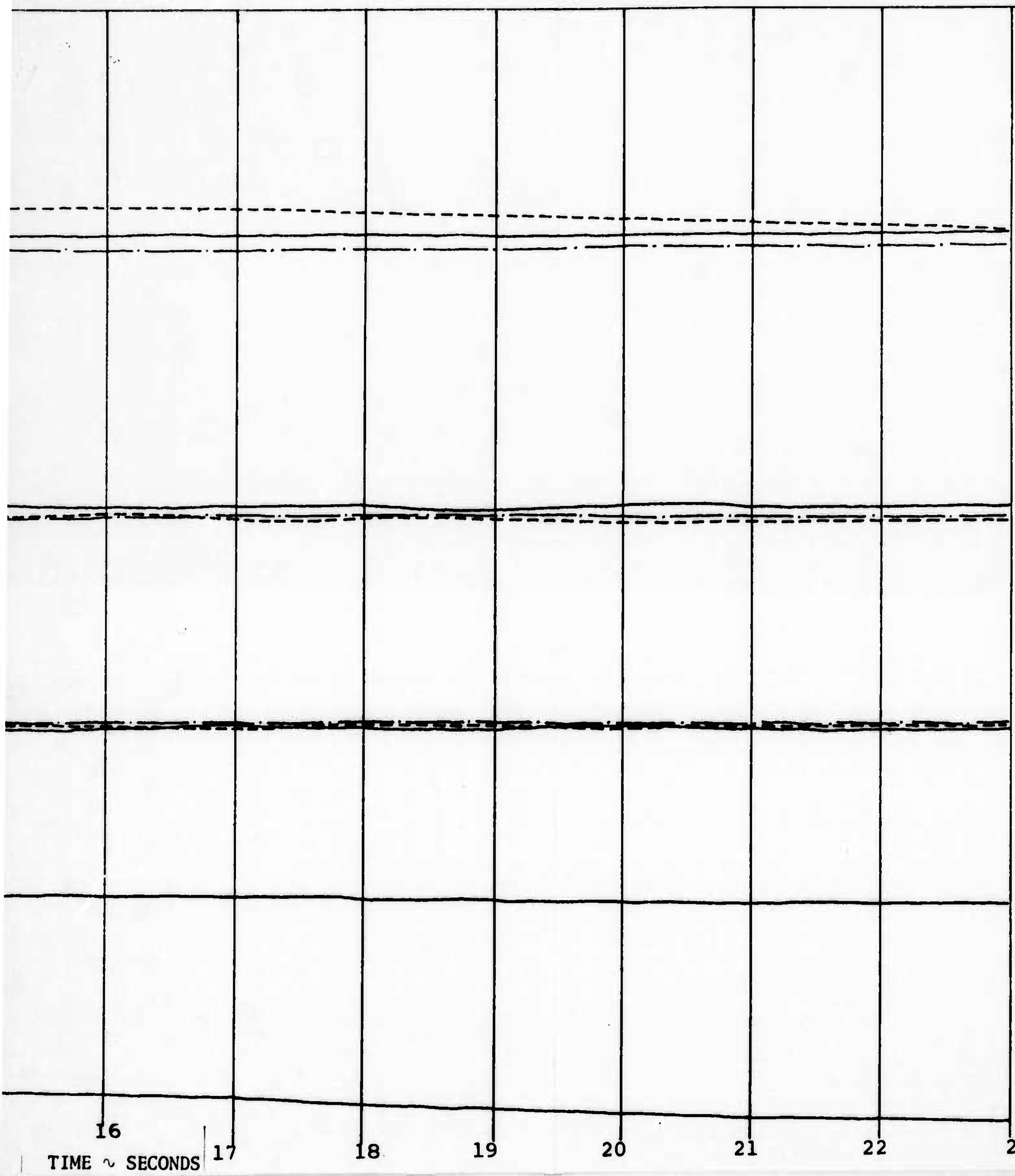


*Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.


LEGEND:
YAW
ROLL
PITCH
PSA CONFIGURATION = ON
TRIM AIRSPEED = 128 KCAS
AVG DENSITY ALTITUDE = 30 FT
SAS CONFIGURATION = ON
PITCH
ATTITUDES ~ DEG
RATES ~DEG/SEC
ANGULAR * ACCELERATIONS ~ DEG/SEC^2
LONG. STK POSN ~ IN
Fwd
Boom A/S ~ Knots
Lt
Rt
Dn
Up
12
13
14
15
TIM

GURE 30 (Continued)
.0 KNOT DECELERATION
-47C USA S/N 66-19121

AVG GROSS WEIGHT = 30670 LB
AVG ROTOR SPEED = 237 RPM
C.G. LOCATION = 2.4 IN AFT
SPEED TRIM (LONG CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO



* Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE 31
COMPARISON OF APE II AND APE III
DYNAMIC STABILITY
YCH-47C USA S/N 66-19121

TRIM A/S (KCAS)	DENSITY ALT. (ft)	G.W. (lb)	ROTOR SPEED (rpm)	C.G. LOC. (in.)
85	3420	42030	246	5.2 Aft (SAS ON, PSA ON, APE III)

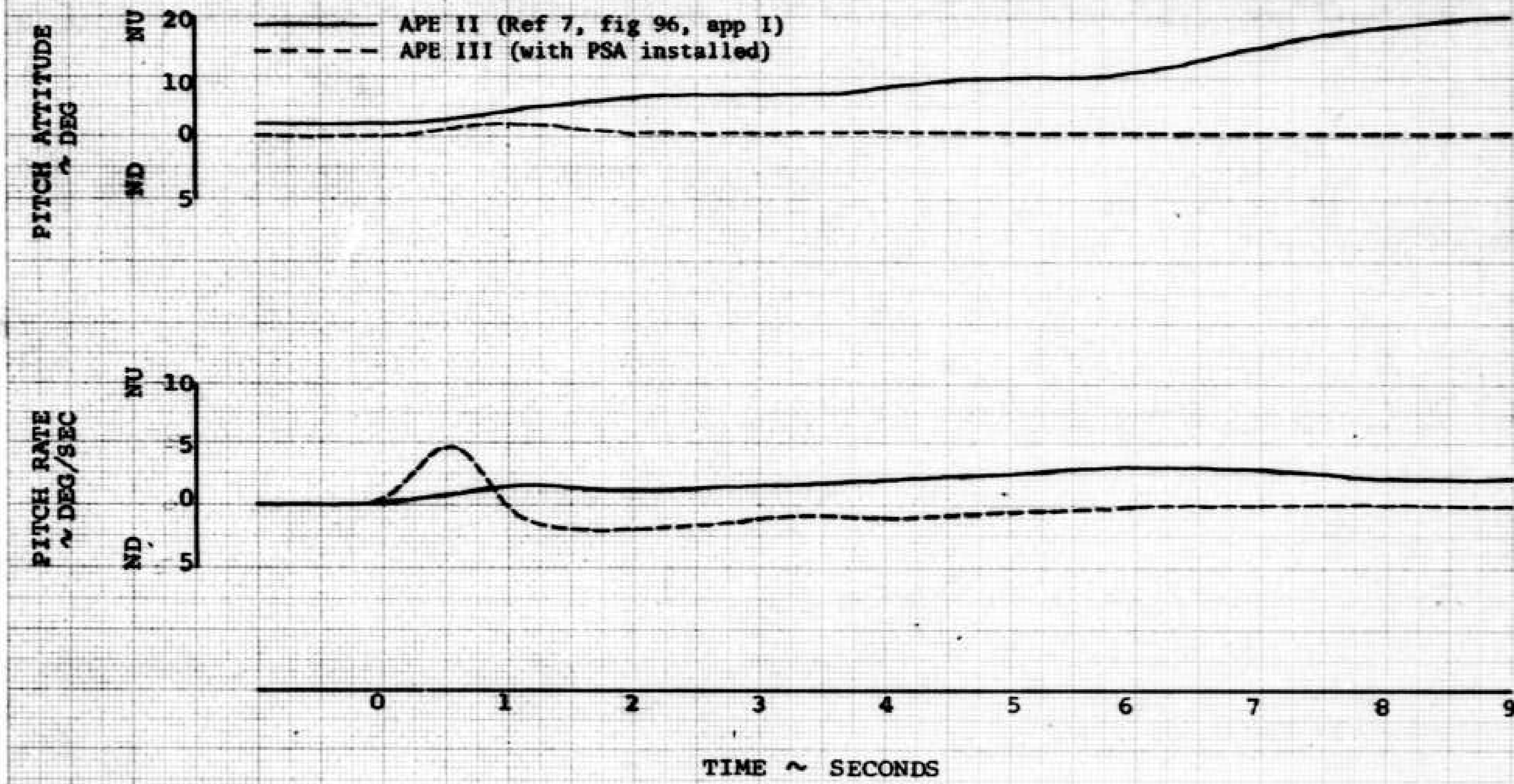
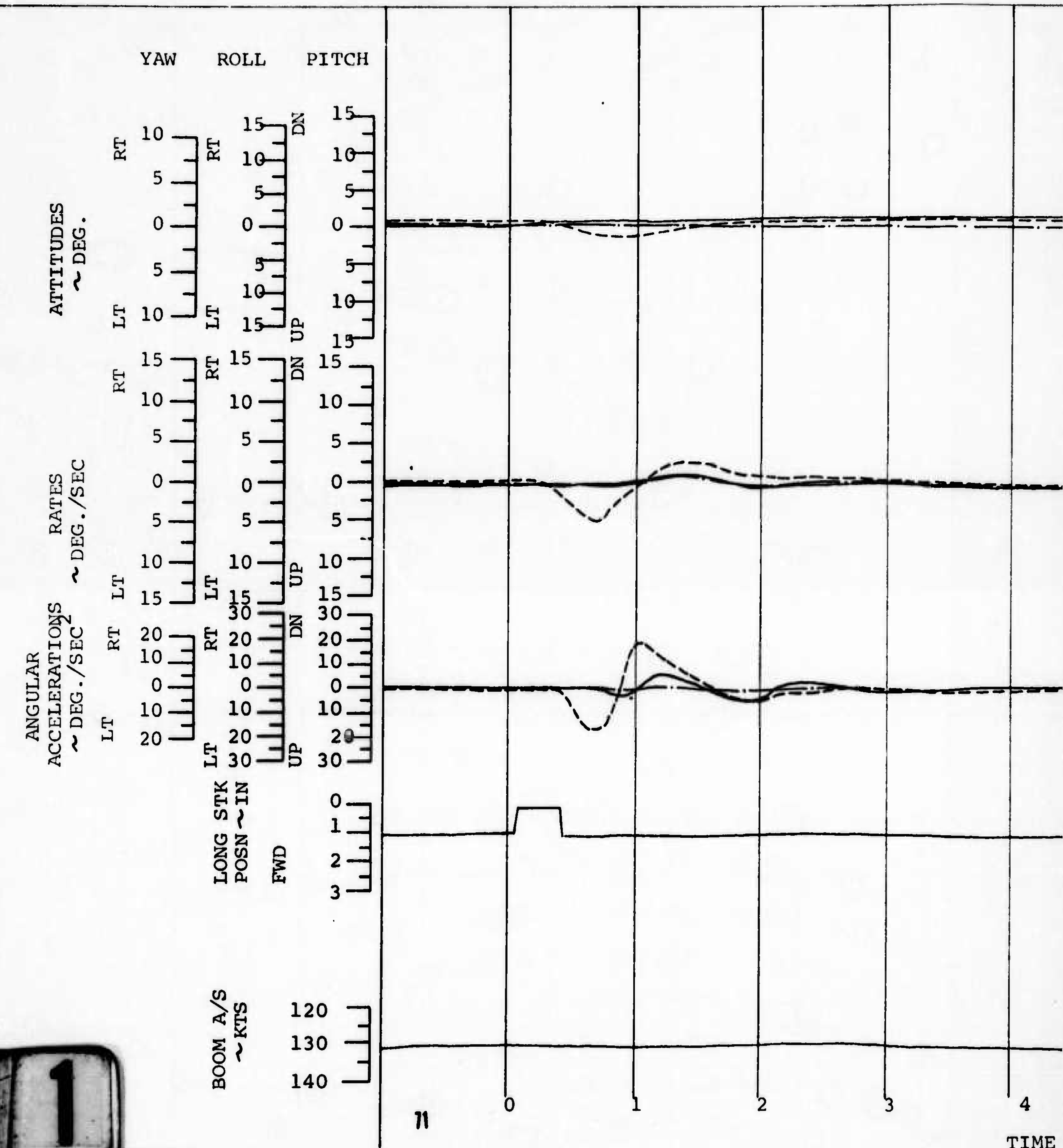


FIGURE 32
AFT LONGITUDINAL PU
YCH-47C USA S/N 66-

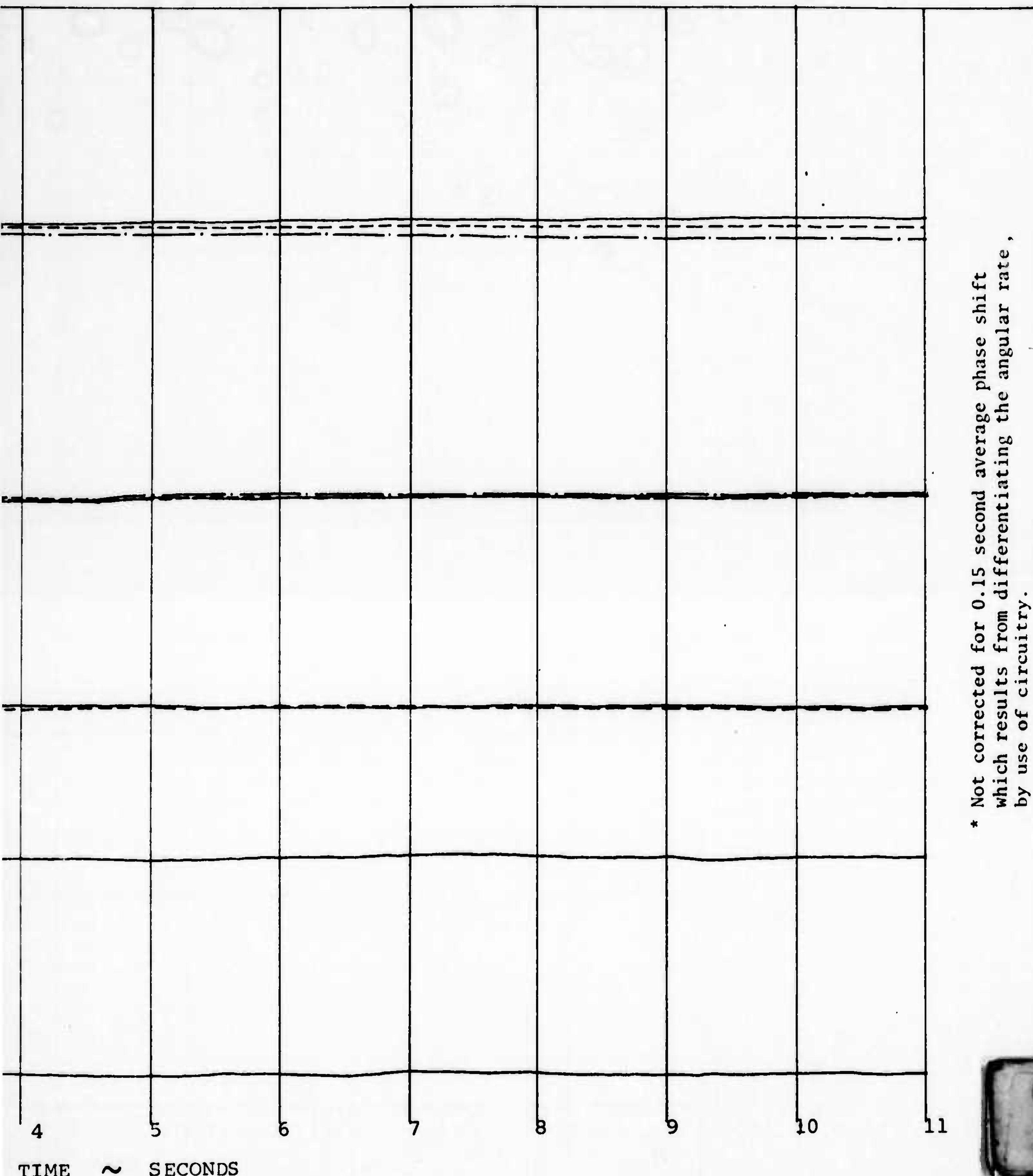
LEGEND:
YAW — · — · —
ROLL ————
PITCH - - - - -

PSA CONFIGURATION = ON
TRIM AIRSPEED = 126 KCAS
AVG. DENSITY ALTITUDE = 4700 FT
SAS CONFIGURATION = SINGLE SAS



E 32
INAL PULSE
S/N 66-19121

AVG. GROSS WEIGHT = 34100 LB
AVG. ROTOR SPEED = 237 RPM
C.G. LOCATION = 8.1 IN AFT
SPEED TRIM (LONG.CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO

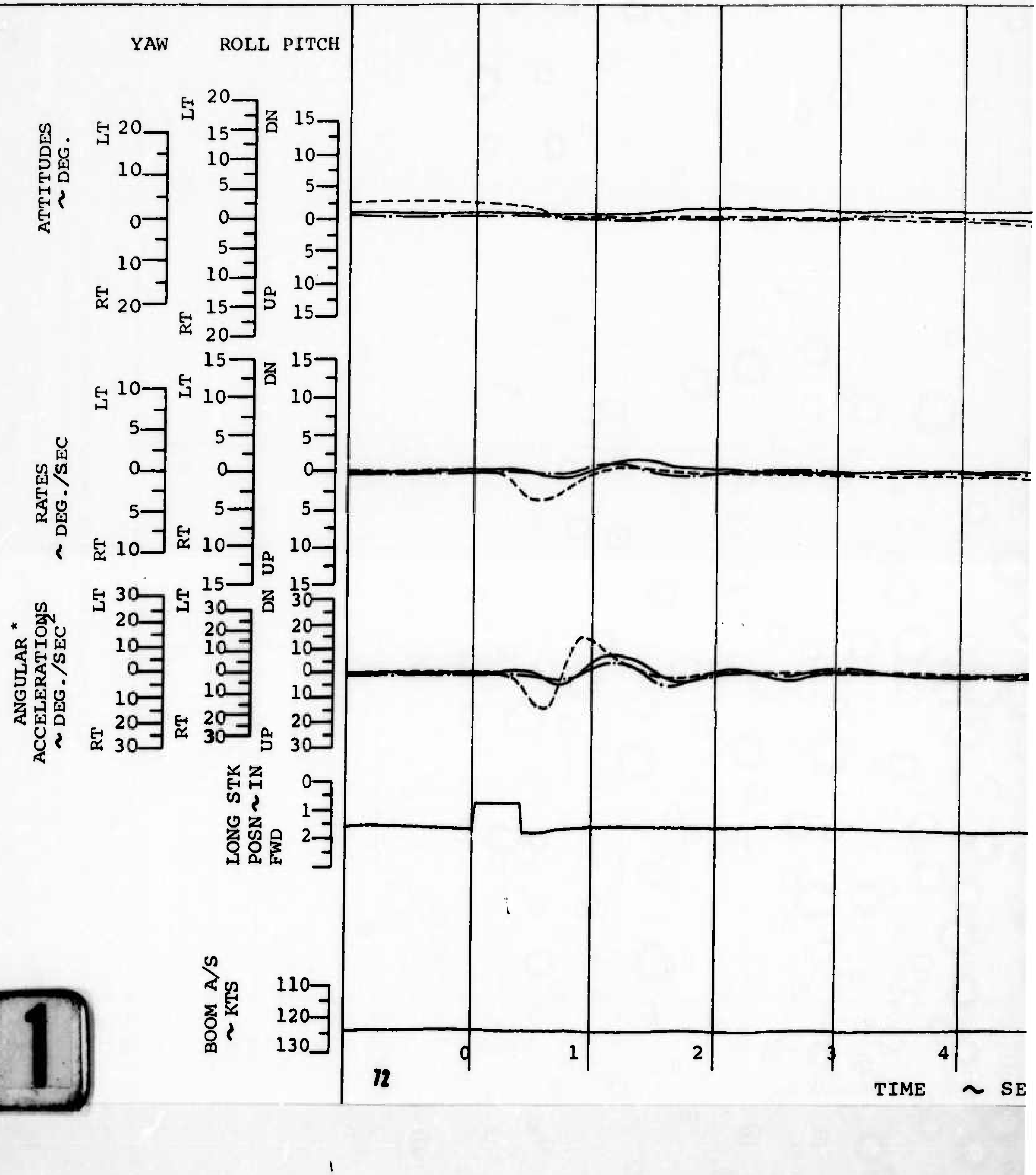


* Not corrected for 0.15 second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE
AFT LONGITUDIN
YCH-47C USA S/

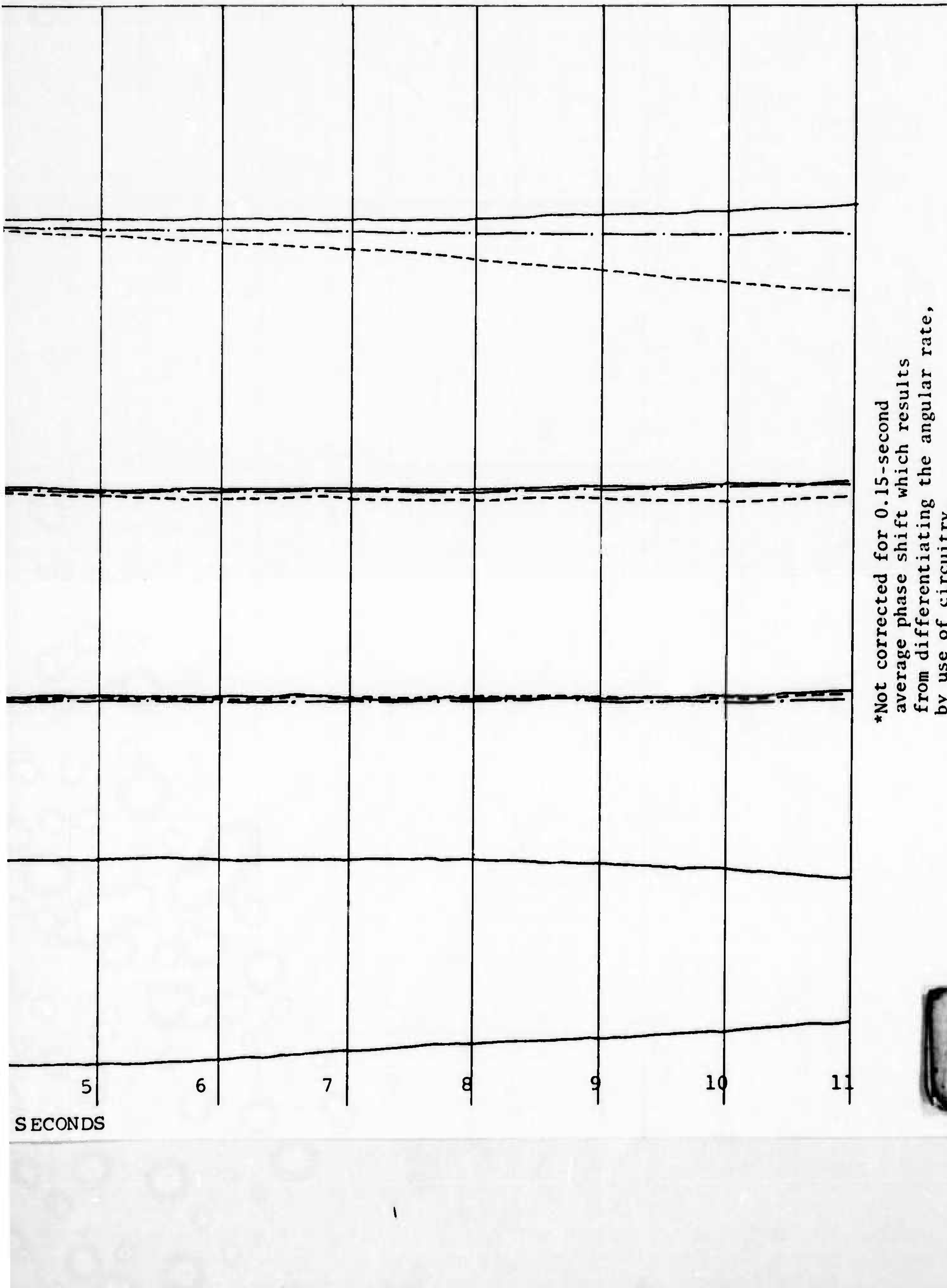
LEGEND:
YAW — · — · —
ROLL ————
PITCH - - - - -

PSA CONFIGURATION = OFF
TRIM AIRSPEED = 130 KCAS
AVG. DENSITY ALTITUDE = 3170 FT
SAS CONFIGURATION = ON



URE 33
UDINAL PULSE
A S/N 66-19121

AVG. GROSS WEIGHT = 43860 LB
AVG. ROTOR SPEED = 246 RPM
C.G. LOCATION = 4.7 IN AFT
SPEED TRIM (LONG. CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO

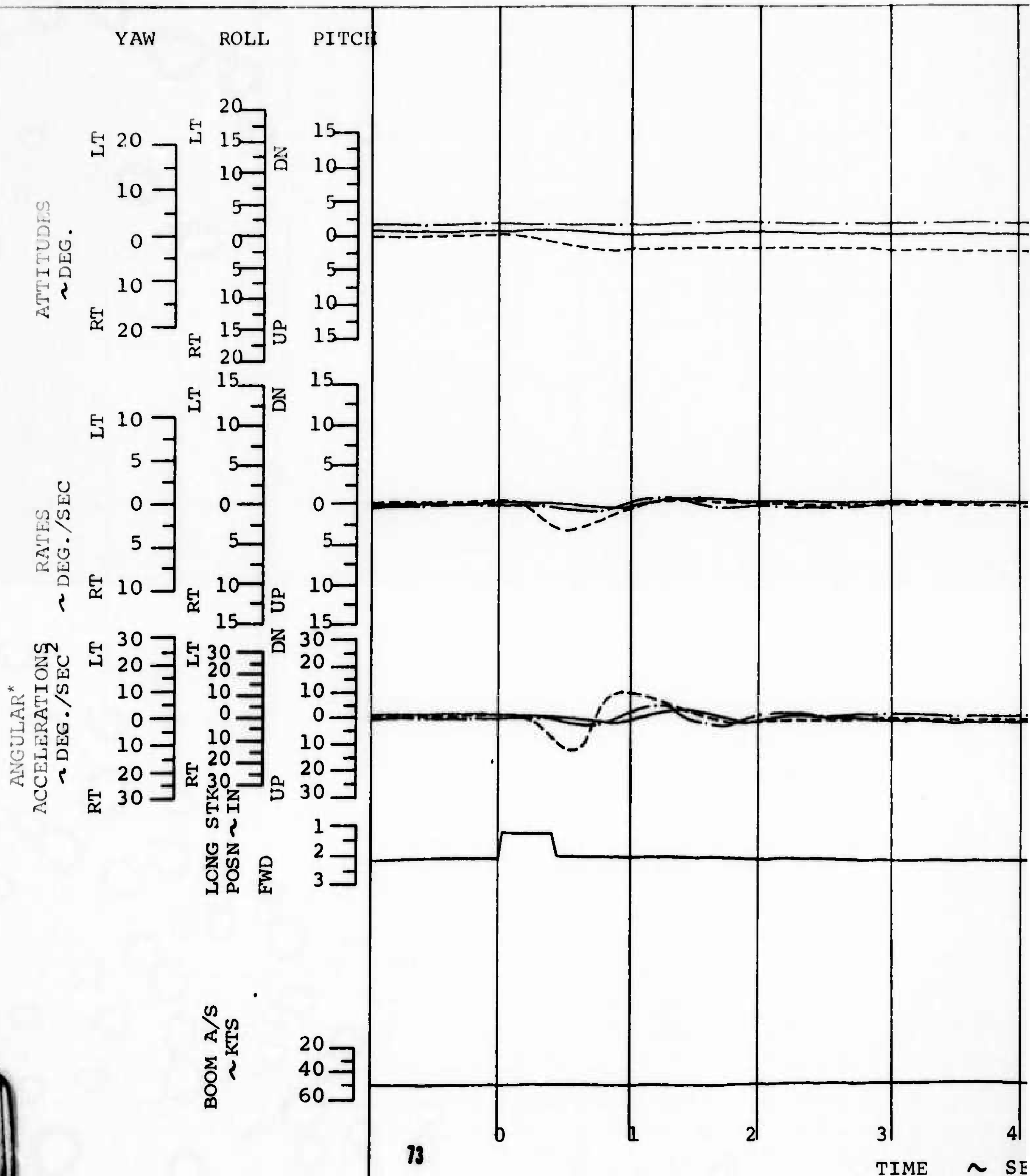


*Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE 34
AFT LONGITUDINAL
YCH-47C USA S/N 6

LEGEND:
YAW — · — · —
ROLL ————
PITCH - - - - -

PSA CONFIGURATION = OFF
TRIM AIRSPEED = 56 KCAS
AVG. DENSITY ALTITUDE = 7200 FT
SAS CONFIGURATION = ON



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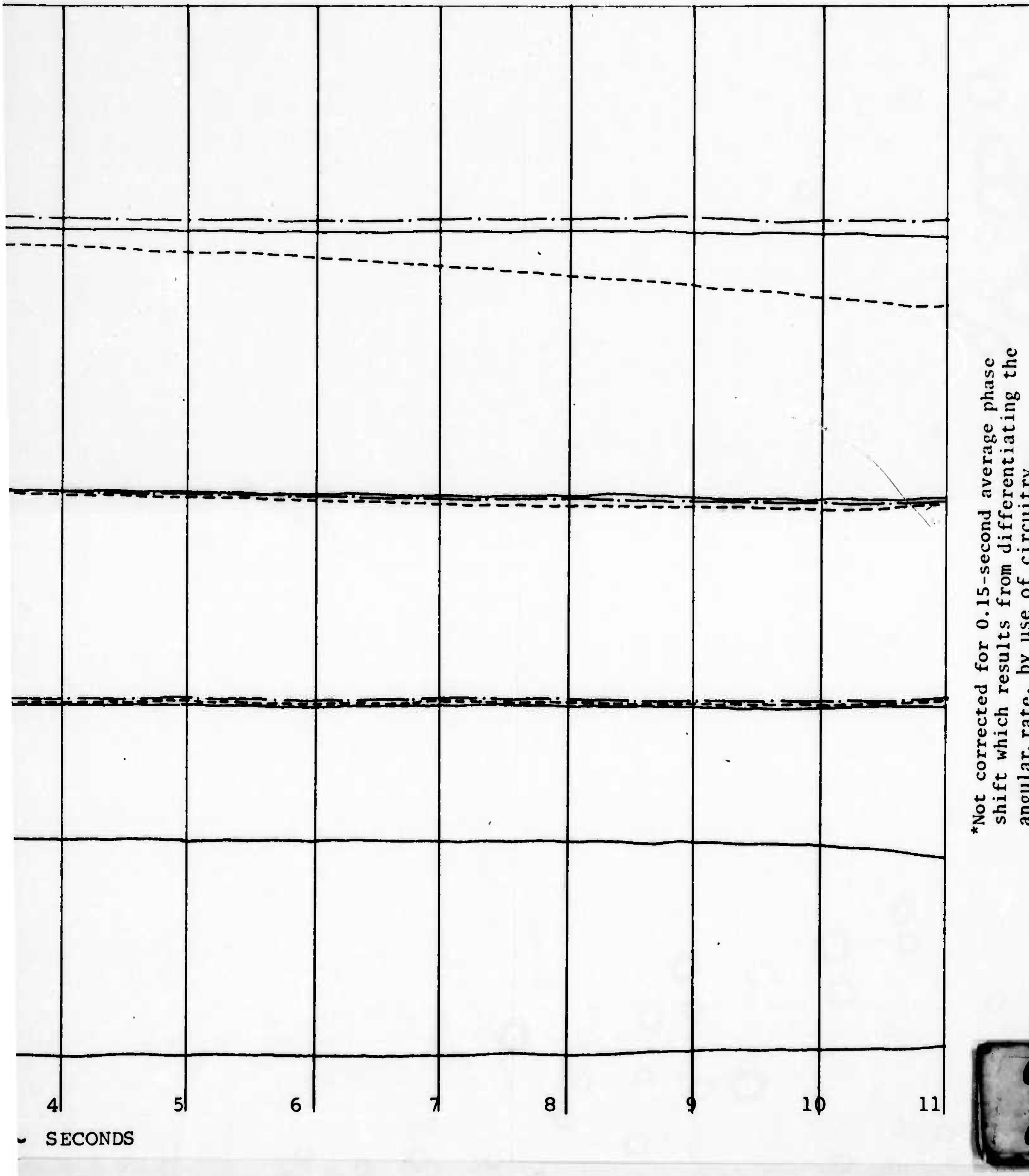
URE 34
UDINAL PULSE
A S/N 66-19121

AVG. GROSS WEIGHT = 45040 LB
AVG. ROTOR SPEED = 246 RPM
C.G. LOCATION = 4.2 IN AFT
SPEED TRIM (LONG CYCLIC) = AUTO
SPEED TRIM (DCP) = AUTO



*Not corrected for 0.15-second average phase shift which results from differentiating the angular rate, by use of circuitry.

FIGURE 35
COMPARISON OF APE II AND APE III
DYNAMIC STABILITY
YCH-47C USA S/N 66-19121

TRIM A/S (KCAS)	DENSITY ALT. (ft)	G.W. (lb)	ROTOR SPEED (rpm)	C.G. LOC. (in.)	CONDITION
85	3700	41840	246	5.3 Aft	PSA OFF SAS ON

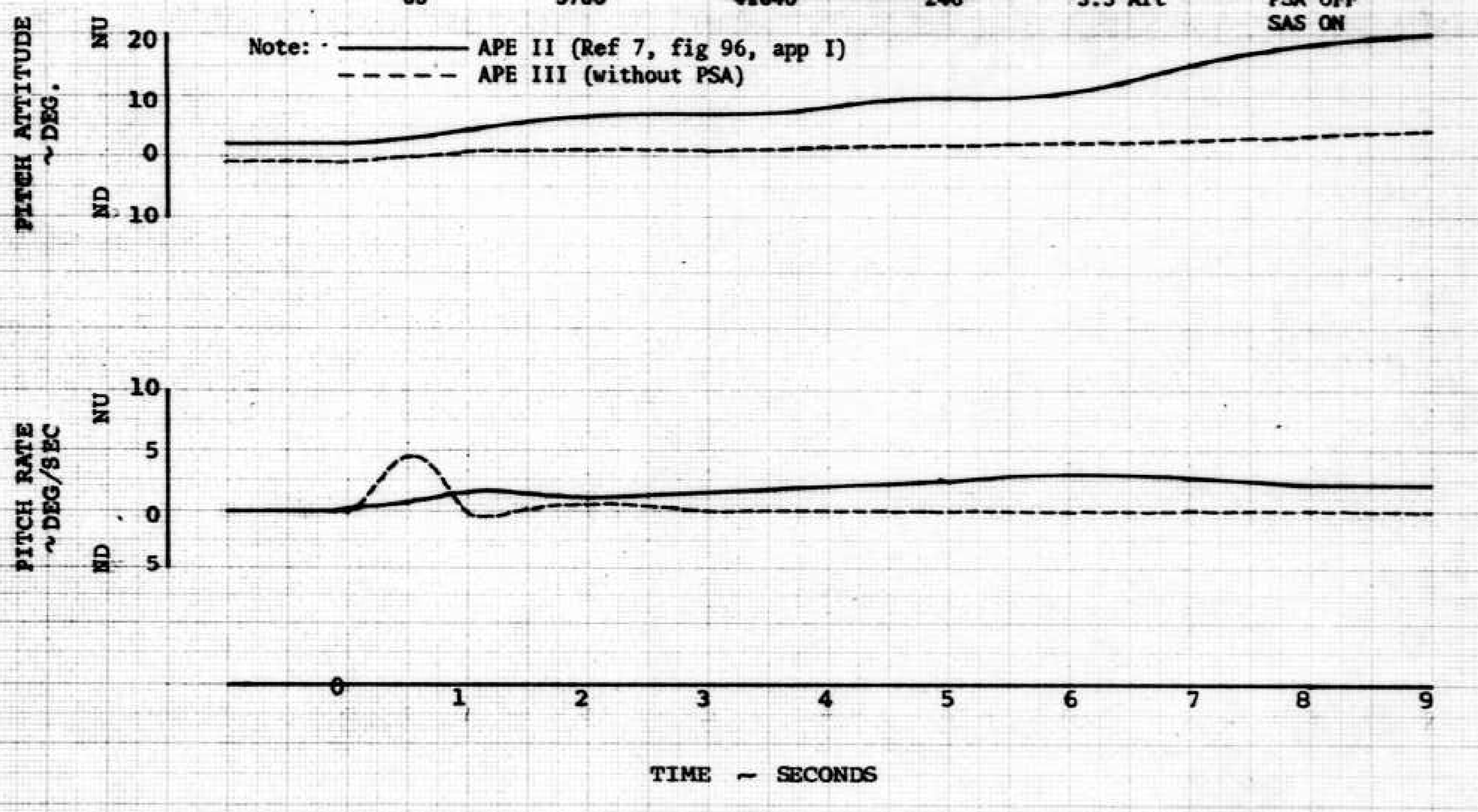


FIGURE 36
TIME HISTORY OF AIRSPEED
FEEDBACK SIGNAL FAILURE
YCH-47C USA S/N 66-19121

TRIM A/S = 75 KTS
DENSITY ALT. = -80 FT
GROSS WT. = 29960 LB

ROTOR SPEED = 237 RPM
C.G. LOCATION = 2.7 In. AFT
Note: Control travel shown in Appendix IV.

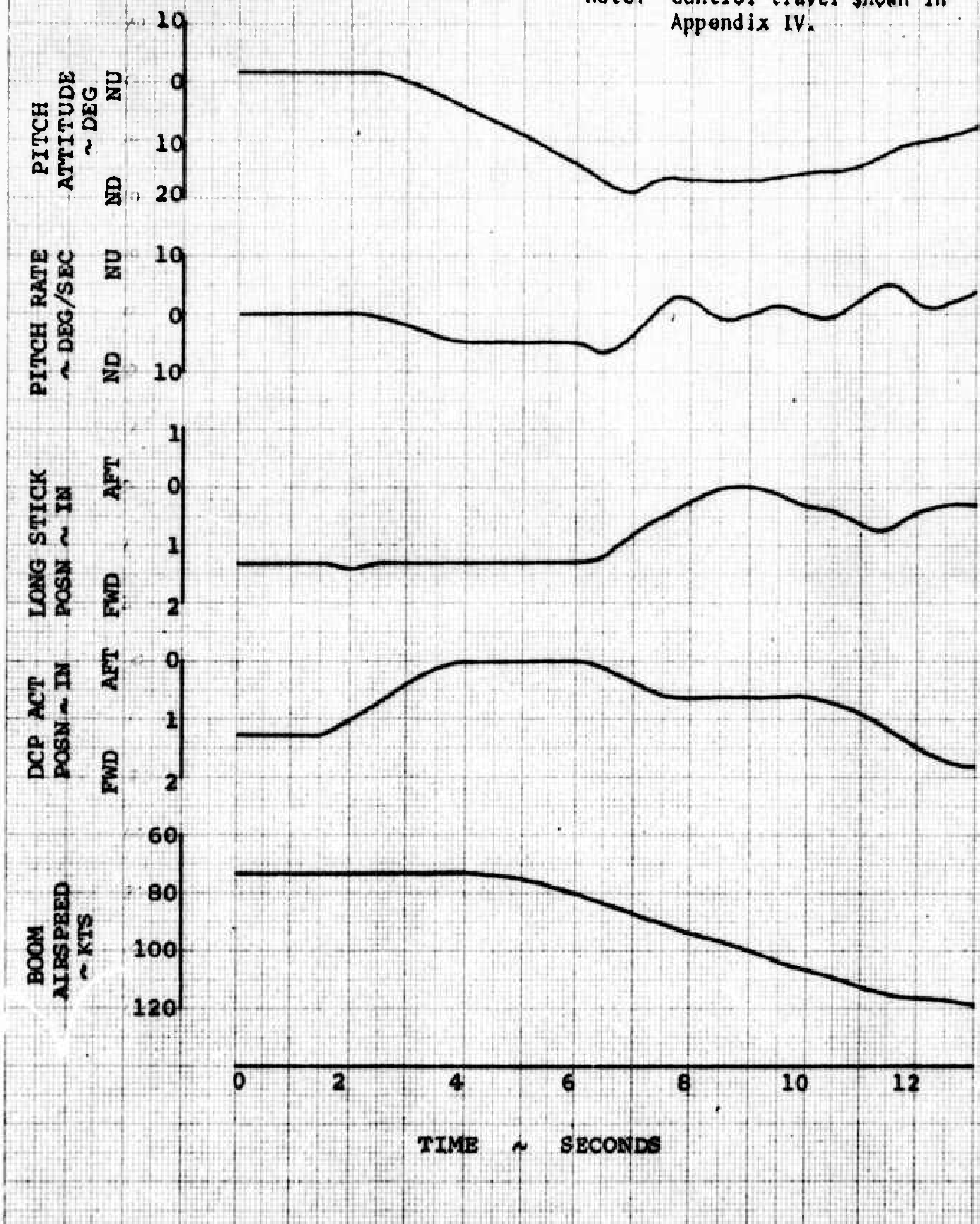


FIGURE 37
TIME HISTORY OF PITCH
ATTITUDE FEEDBACK SIGNAL FAILURE
YCH-47C USA S/N 66-19121

TRIM A/S = 77 KTS
DENSITY ALT = 0.0 FT
GROSS WT = 30,120 LB

ROTOR SPEED = 237 RPM
C.G. LOC. = 2.9 In. AFT

Note: Control travel shown in Appendix IV.

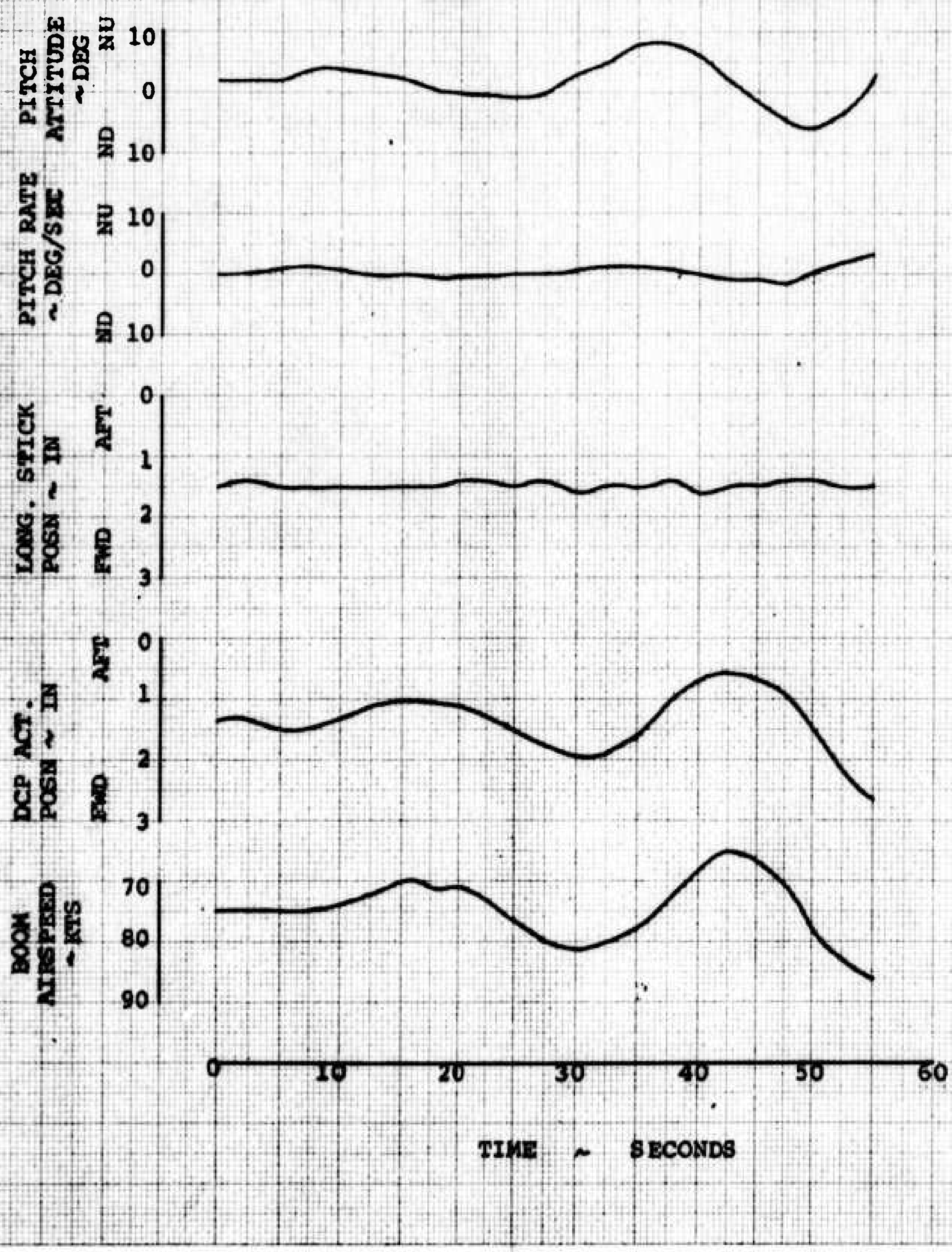


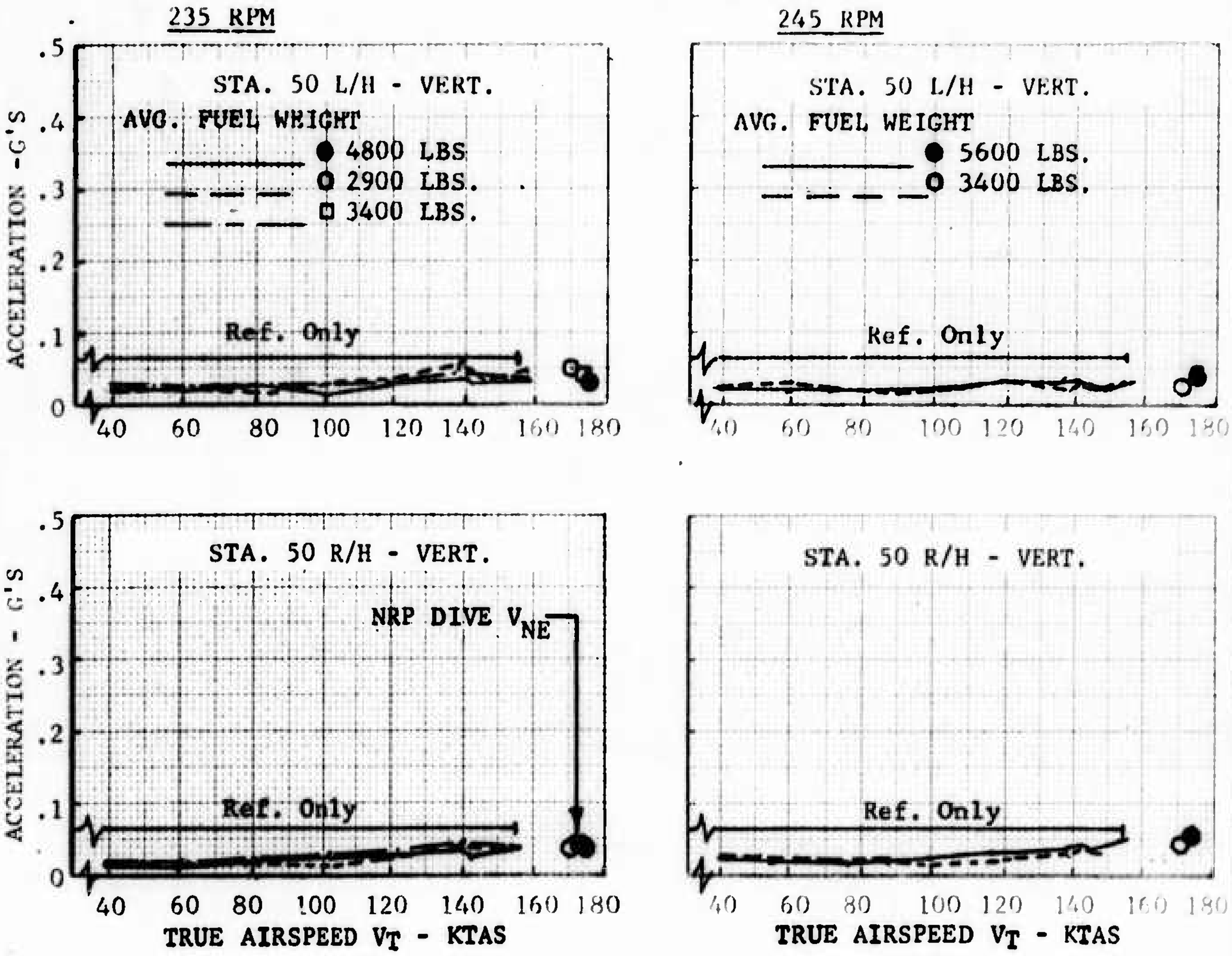
FIGURE 38

1/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS*

AVG. CG = 3.5" FWD
AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C

AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LBS.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO



* LEVELS PRESENTED IN ACCORDANCE WITH DEVIATION 12, REFERENCE 12, APPENDIX I. APPLICABLE TO FIGURES 38 THROUGH 48 AND FIGURE 64.

FIGURE 39

1/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD	AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C	OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LBS.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

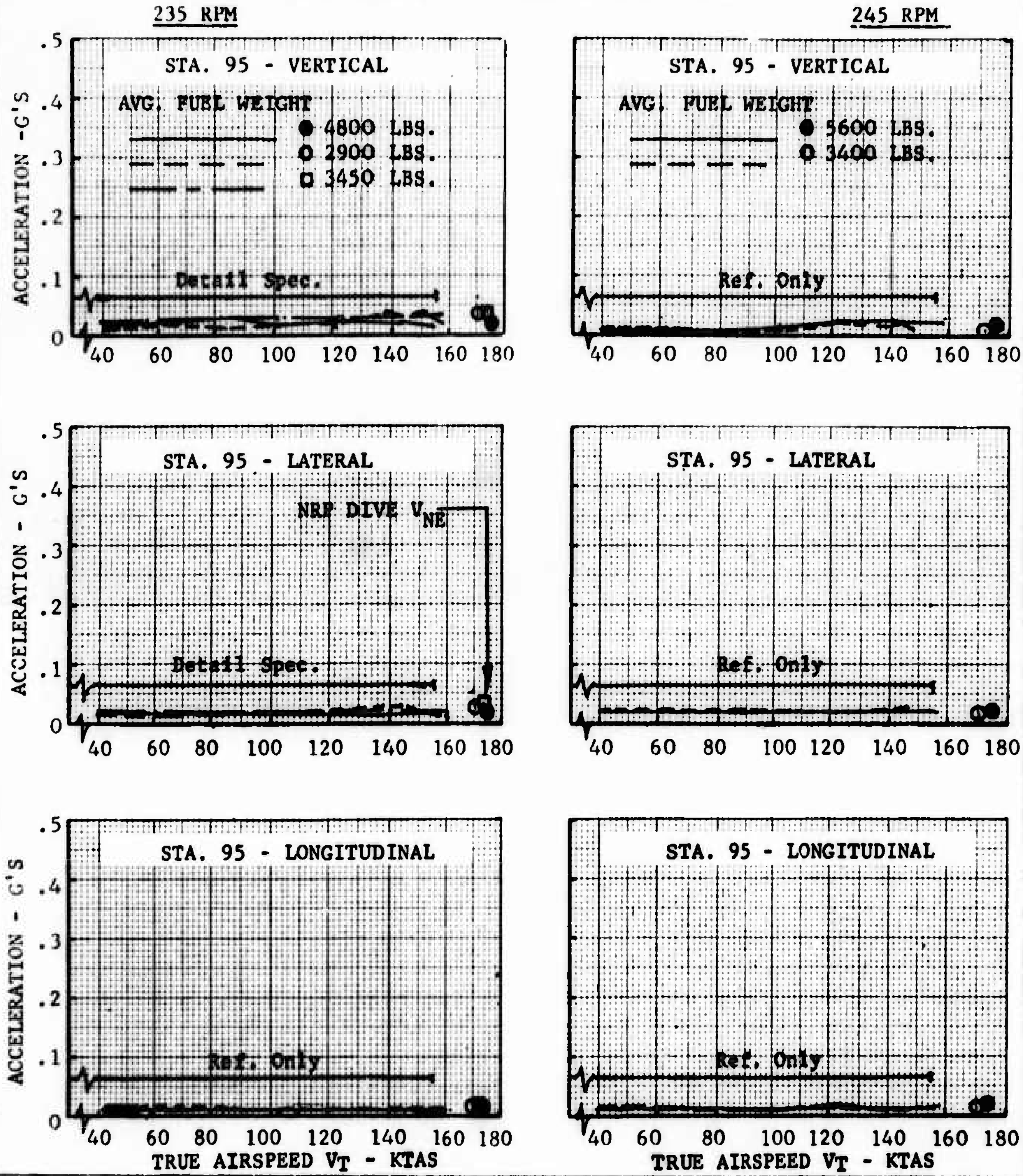


FIGURE 40

1/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD	AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE - 1000 FT.
OUTSIDE AIR TEMPERATURE =+8°C	OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LBS.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

235 RPM 245 RPM

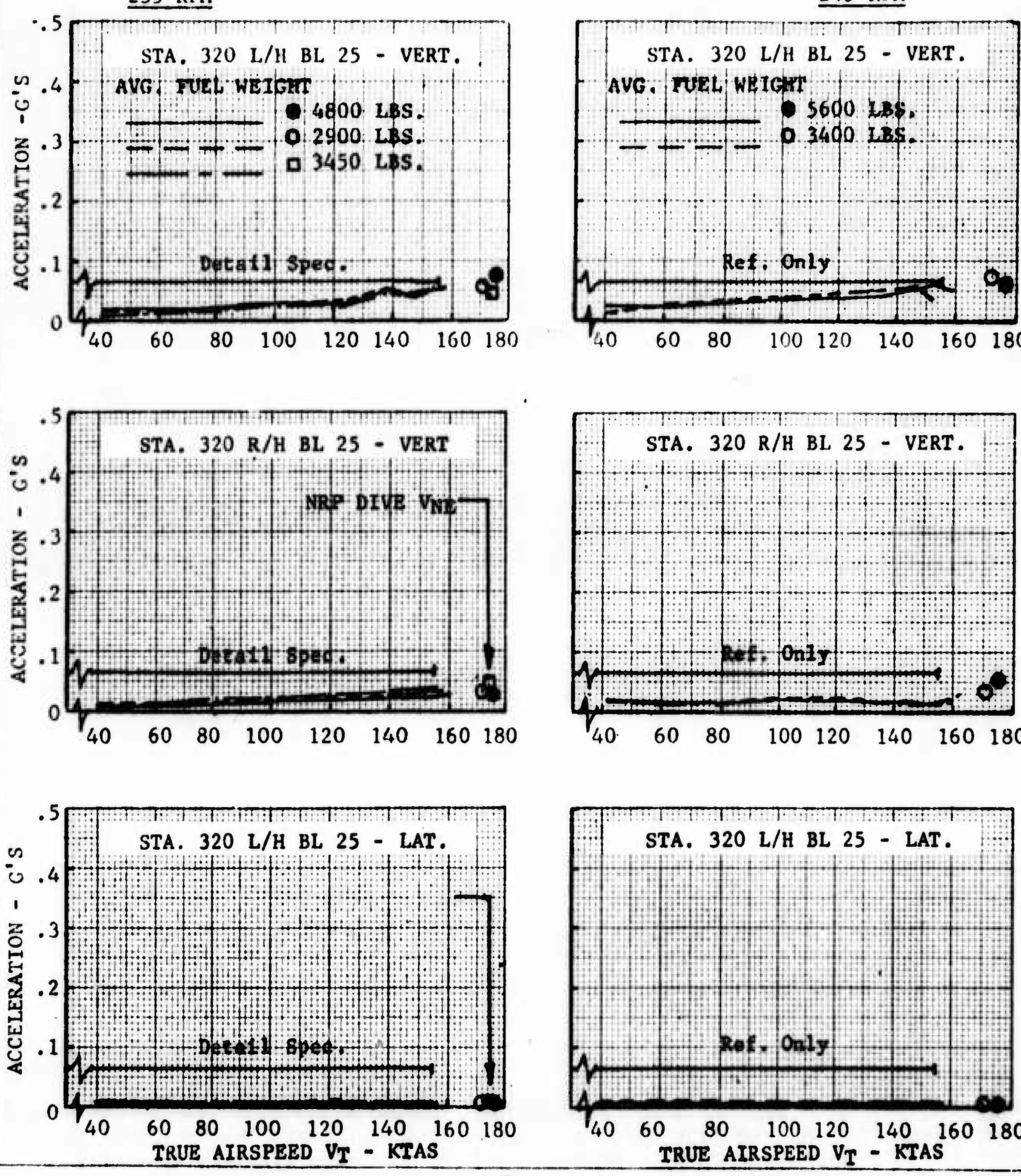


FIGURE 41

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD
AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C

AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

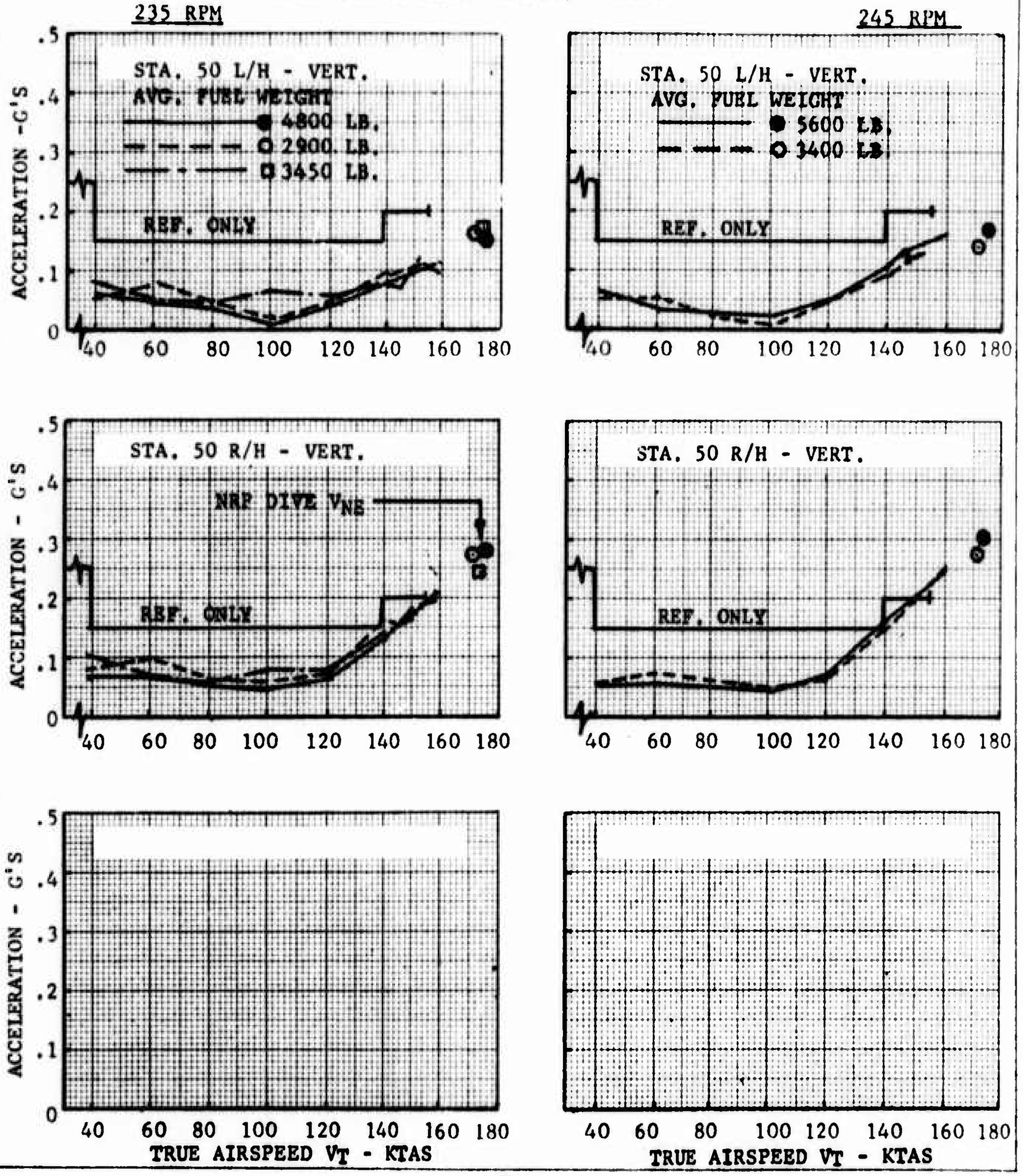


FIGURE 42

3/REV VIBRATION CHARACTERISTICS

CH-47C USA S/N 68-15858

LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD	AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C	OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.

SAS AND PSA CONFIGURATION = ON

SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

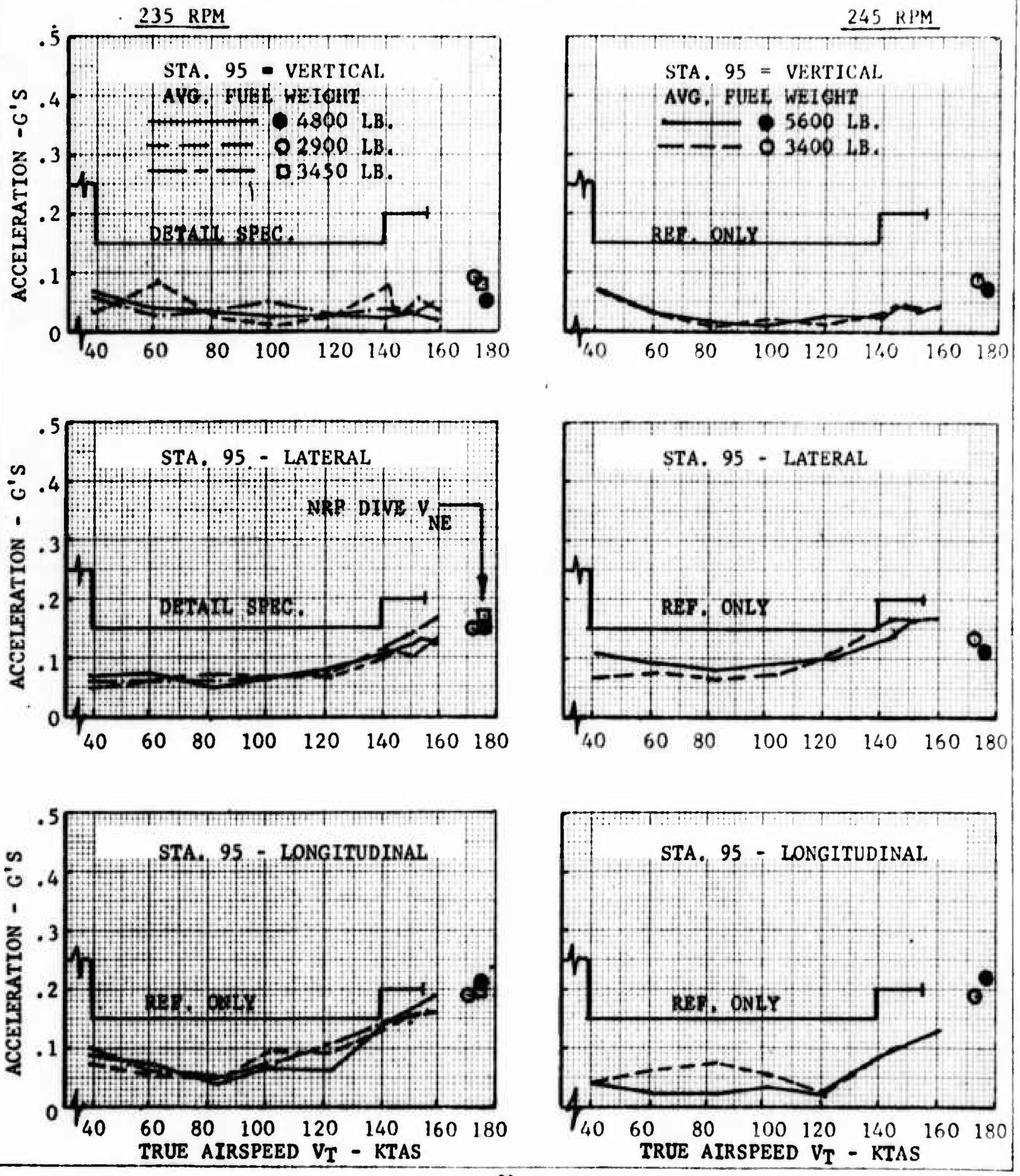


FIGURE 43

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD	AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C	OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

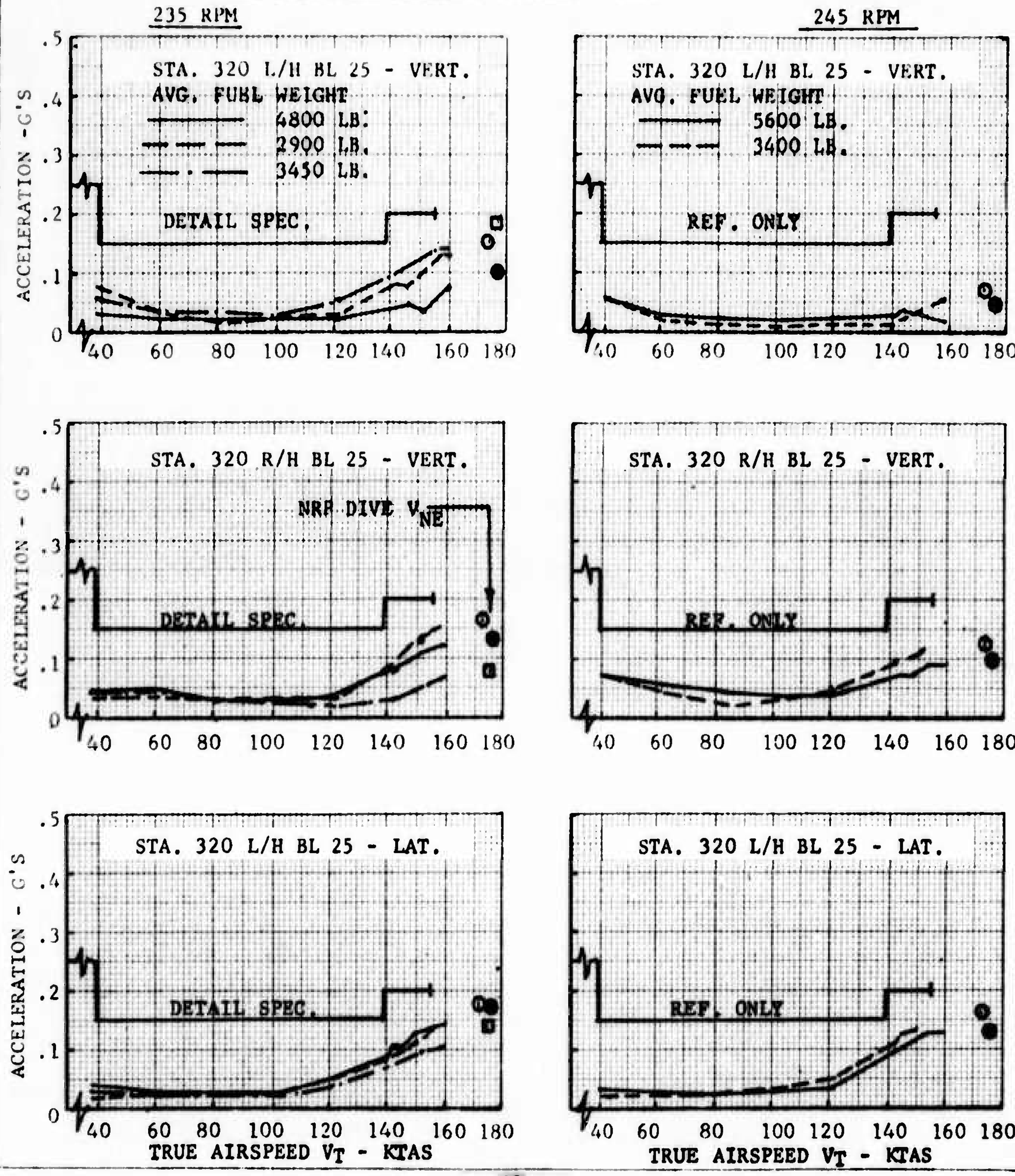


FIGURE 44

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD	AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C	OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

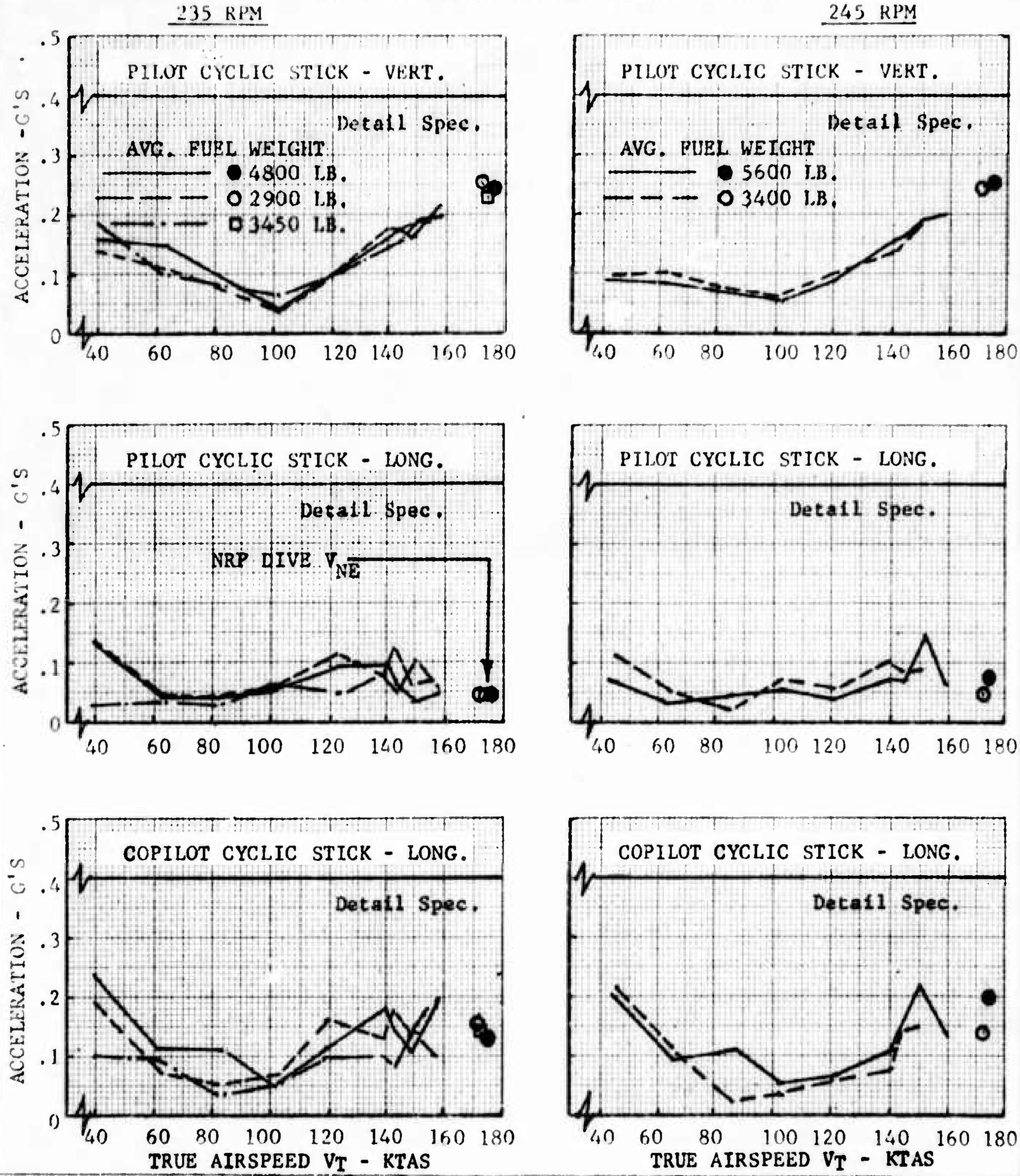


FIGURE 45

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD	AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C	OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

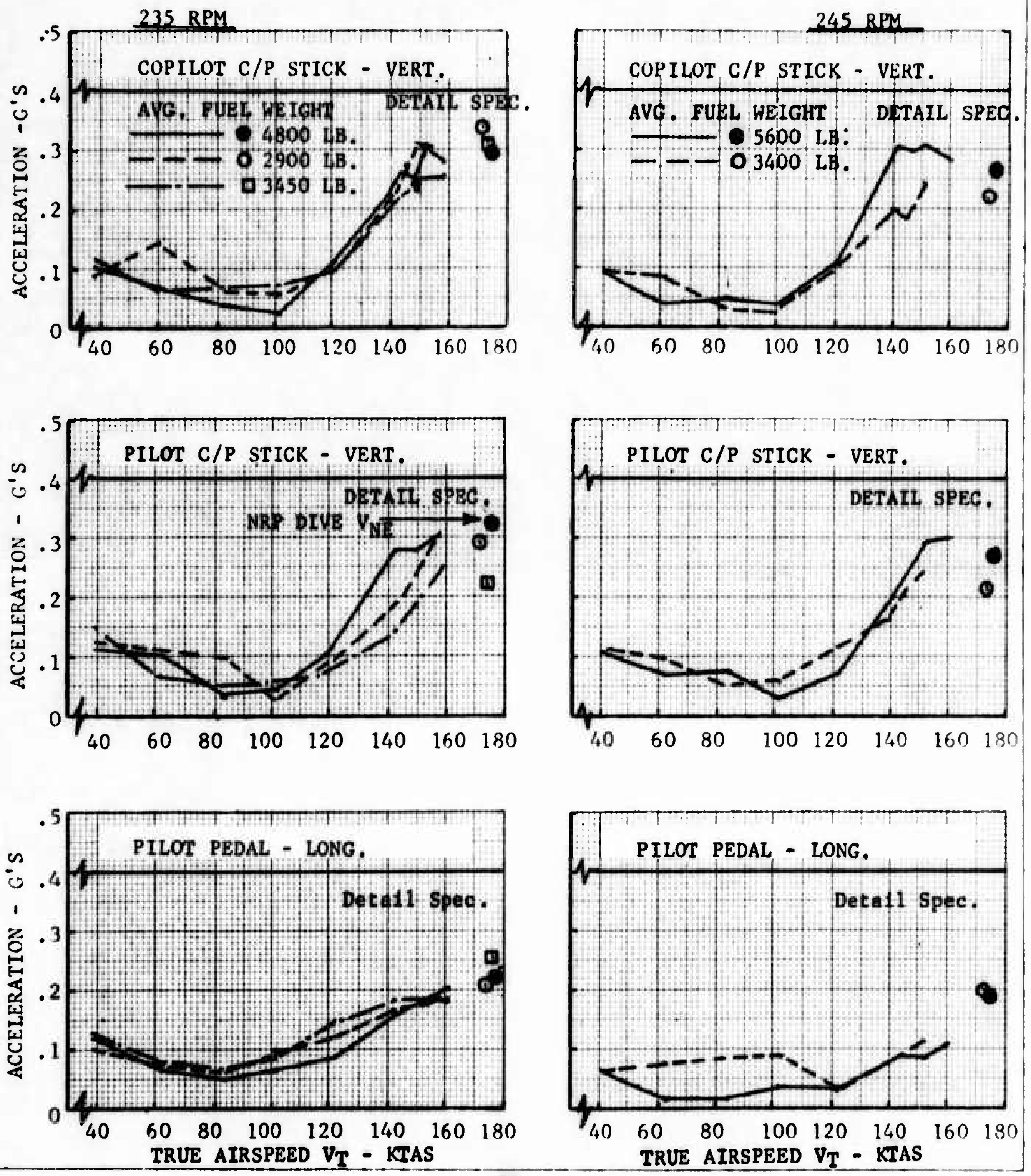


FIGURE 46

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD	AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C	OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

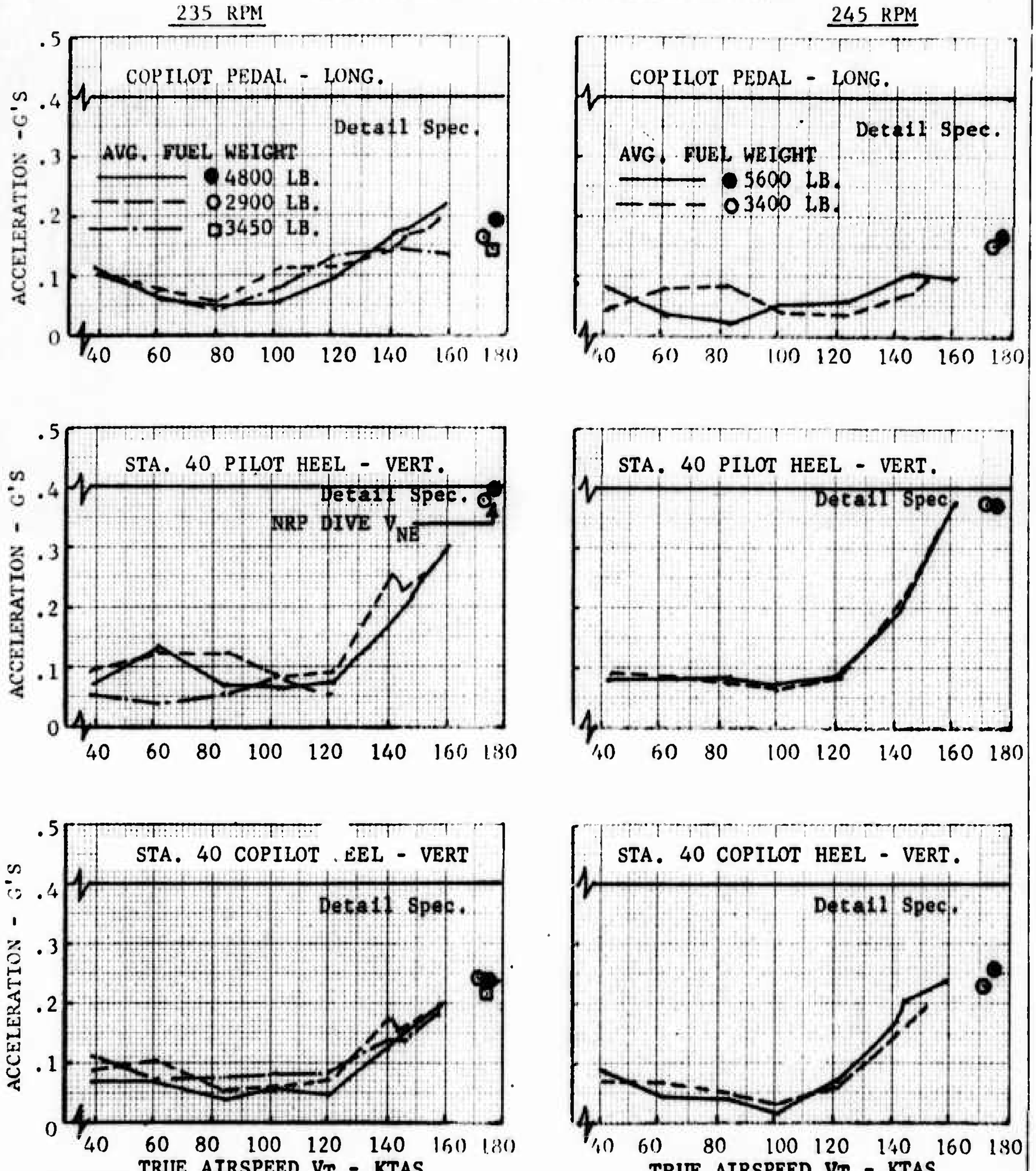


FIGURE 47

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 3.5" FWD — AVG. CG = 3.8" FWD
AVG. DENSITY ALTITUDE = 1000 FT. — AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C — OUTSIDE AIR TEMPERATURE = +9°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

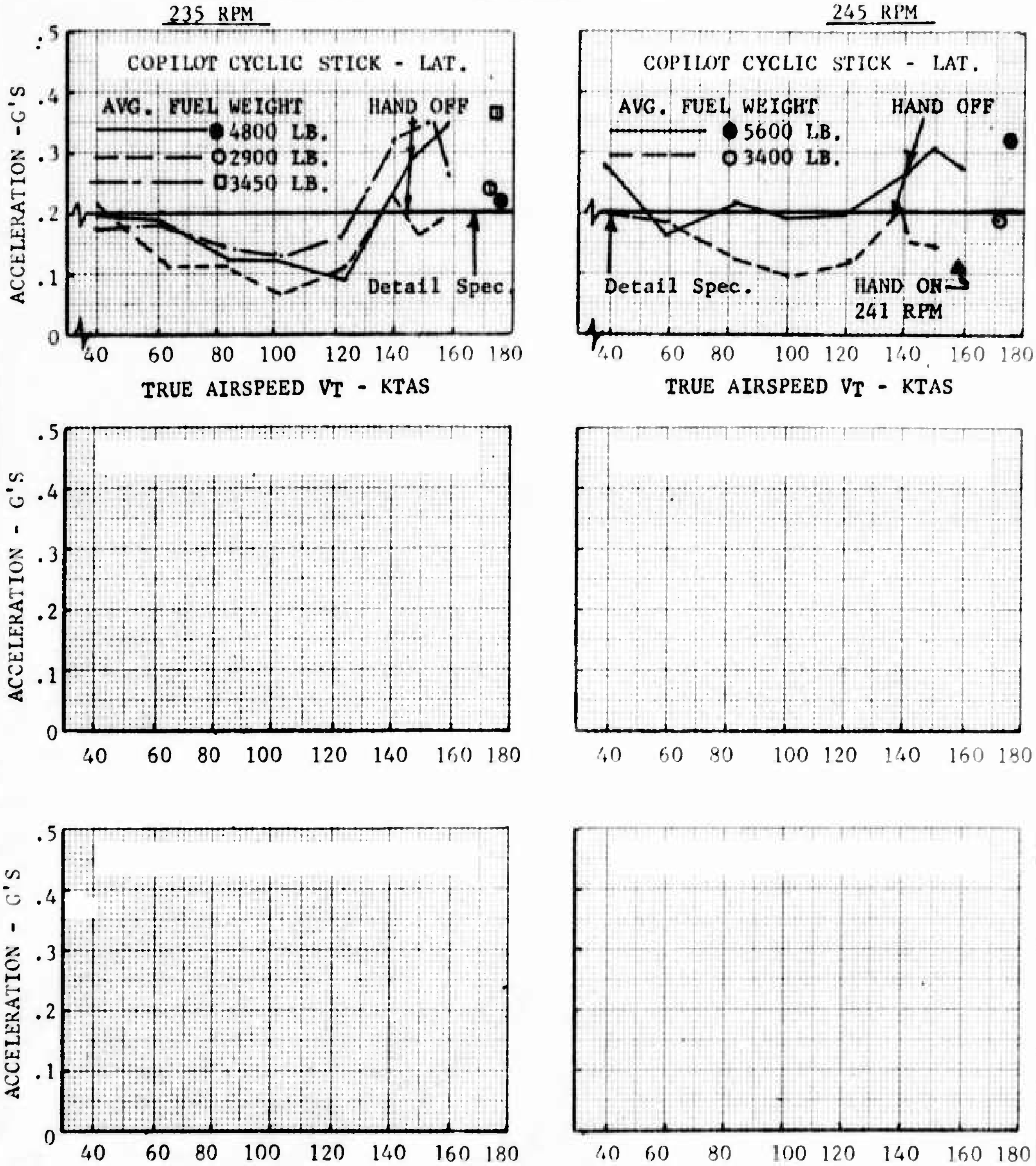


FIGURE 48

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
ROTOR RPM SWEEP

AVG. CG = 3.8"FWD	AVG. CG = 3.7" FWD
AVG. DENSITY ALTITUDE = 1000 FT.	AVG. DENSITY ALTITUDE = 1200 FT.
OUTSIDE AIR TEMPERATURE = +14°C	OUTSIDE AIR TEMPERATURE = +13°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
SAS and PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO
85% VIB. LEVELS *

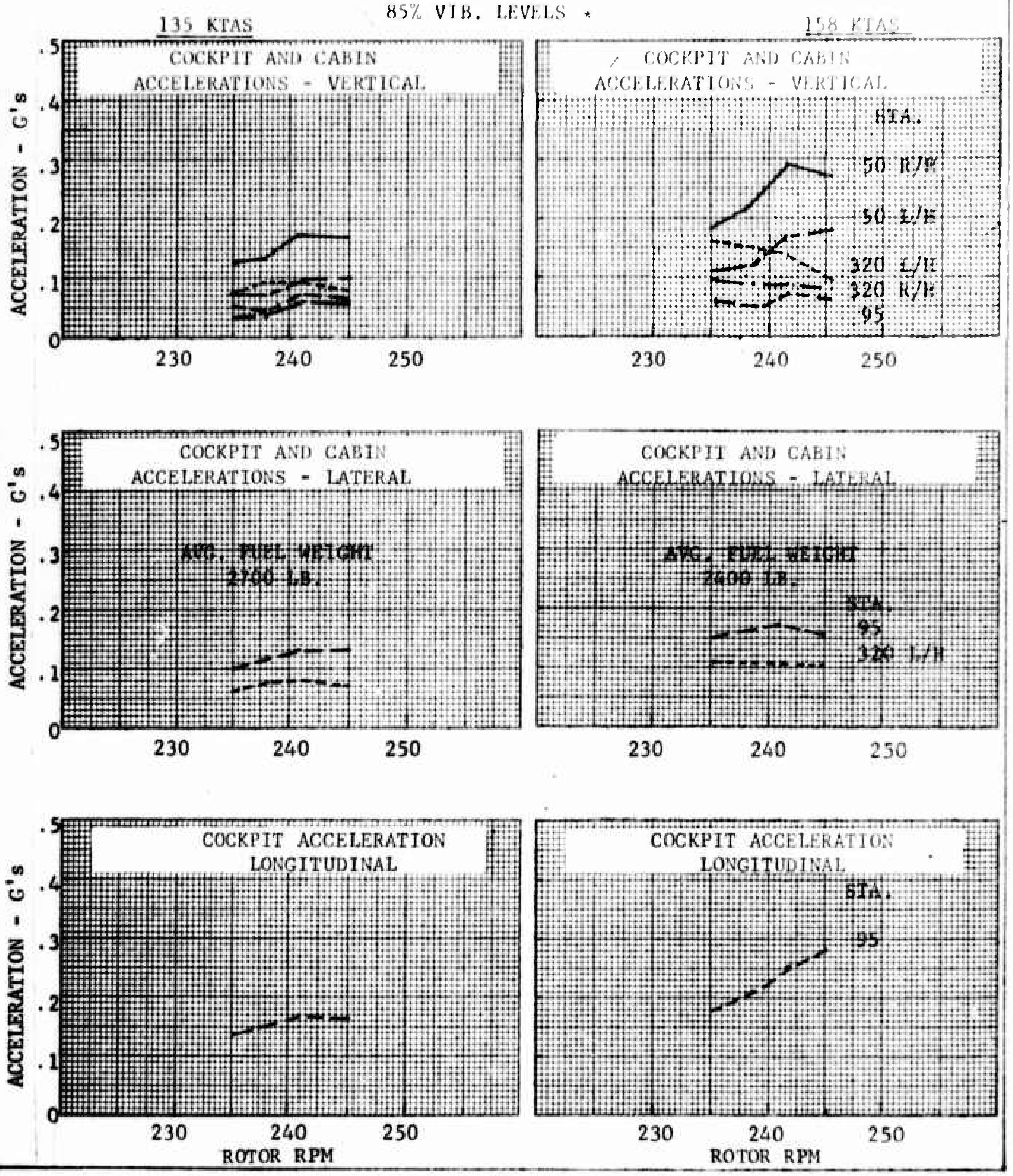


FIGURE 49
1/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

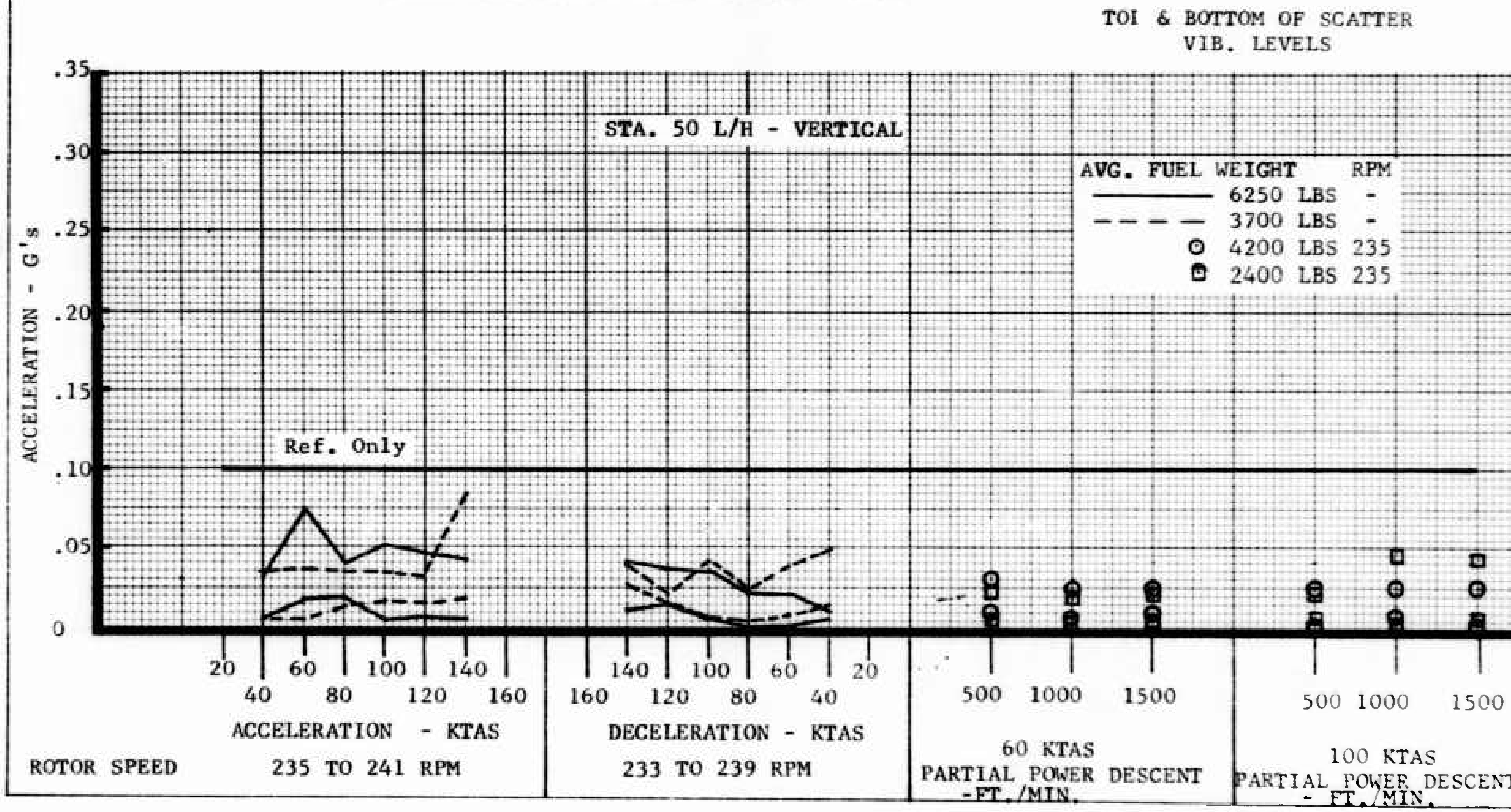


FIGURE 50
1/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
<u>MANEUVER DATA</u>

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. CG = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

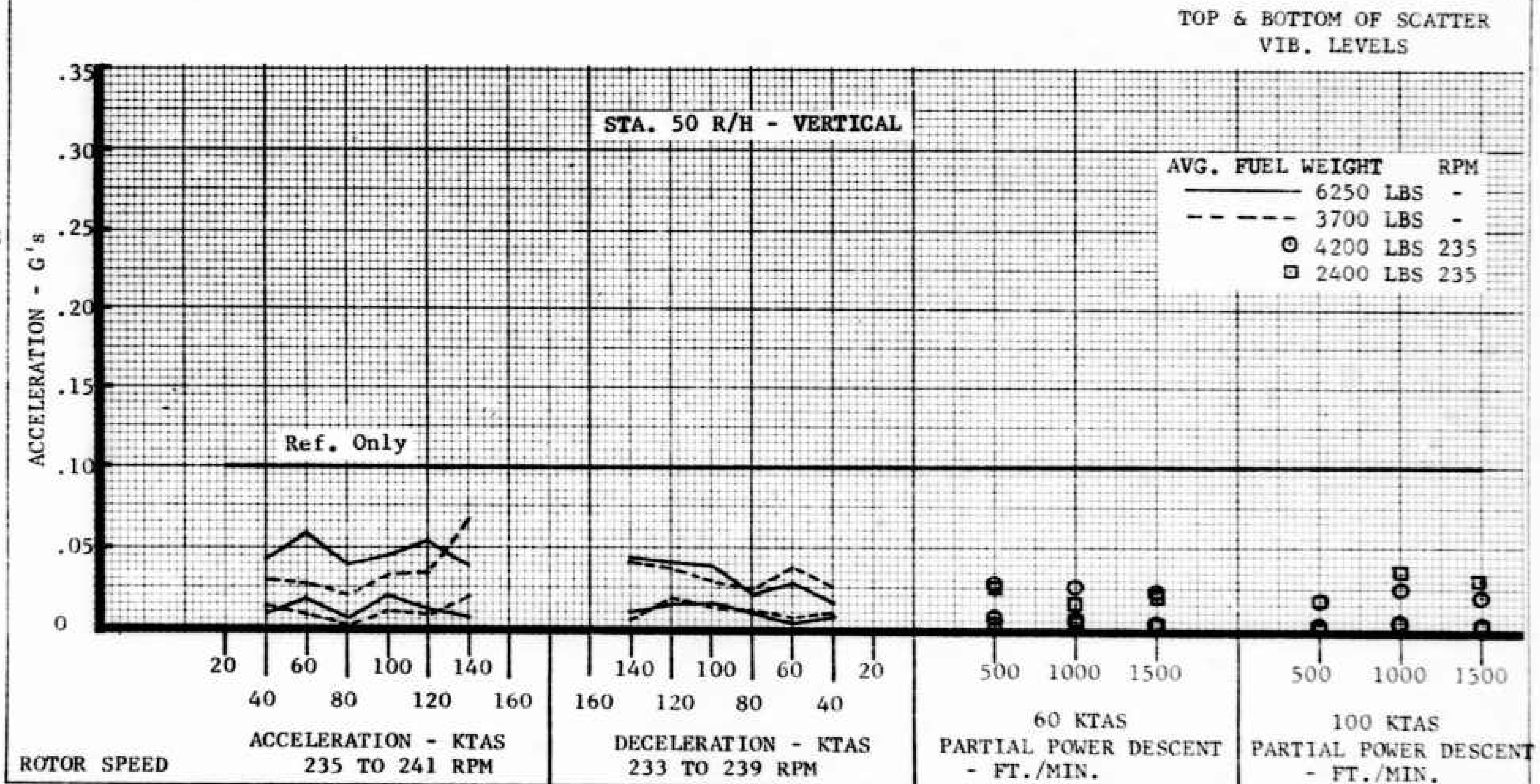


FIGURE 51
1/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

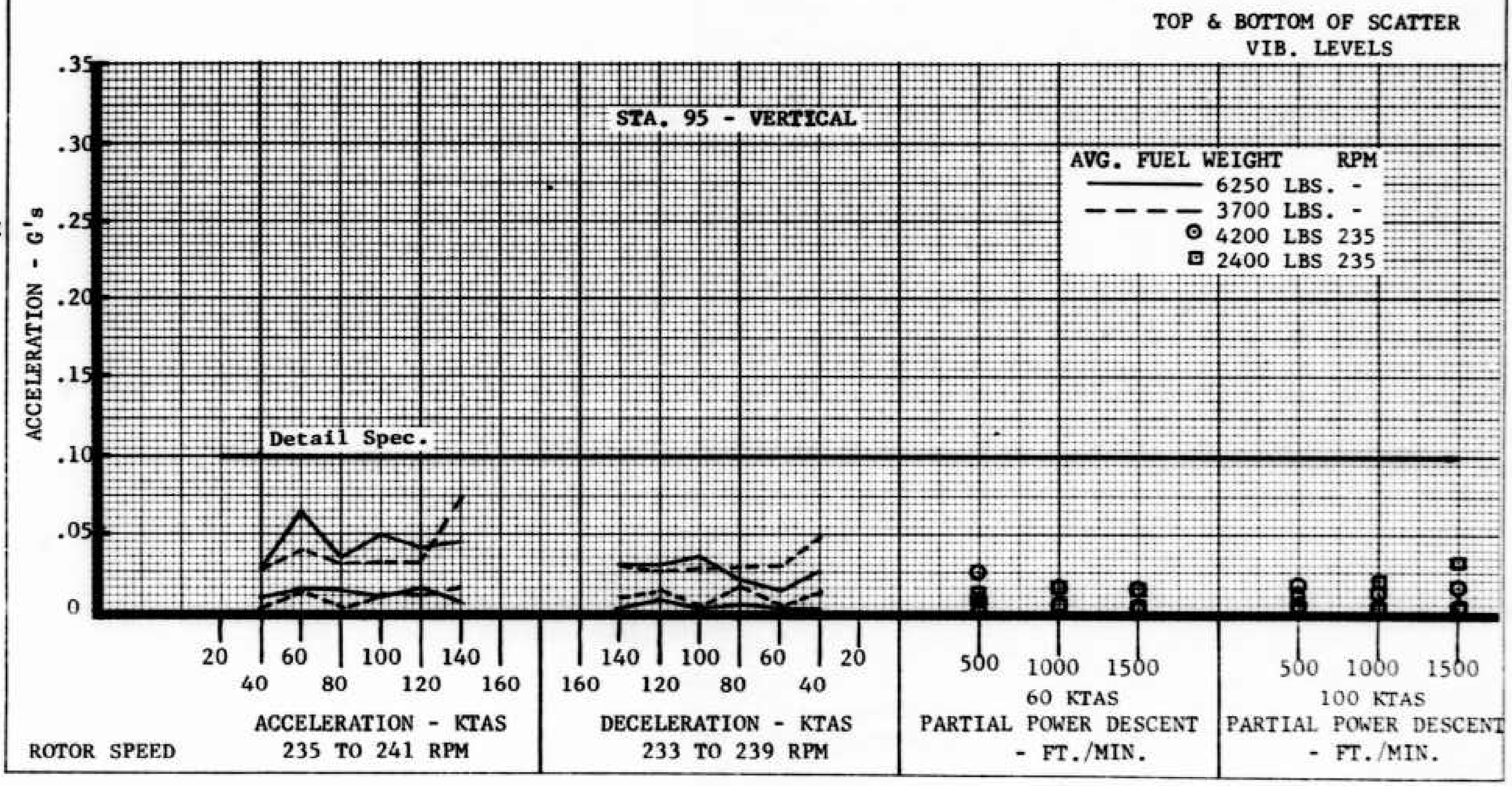


FIGURE 52
1/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

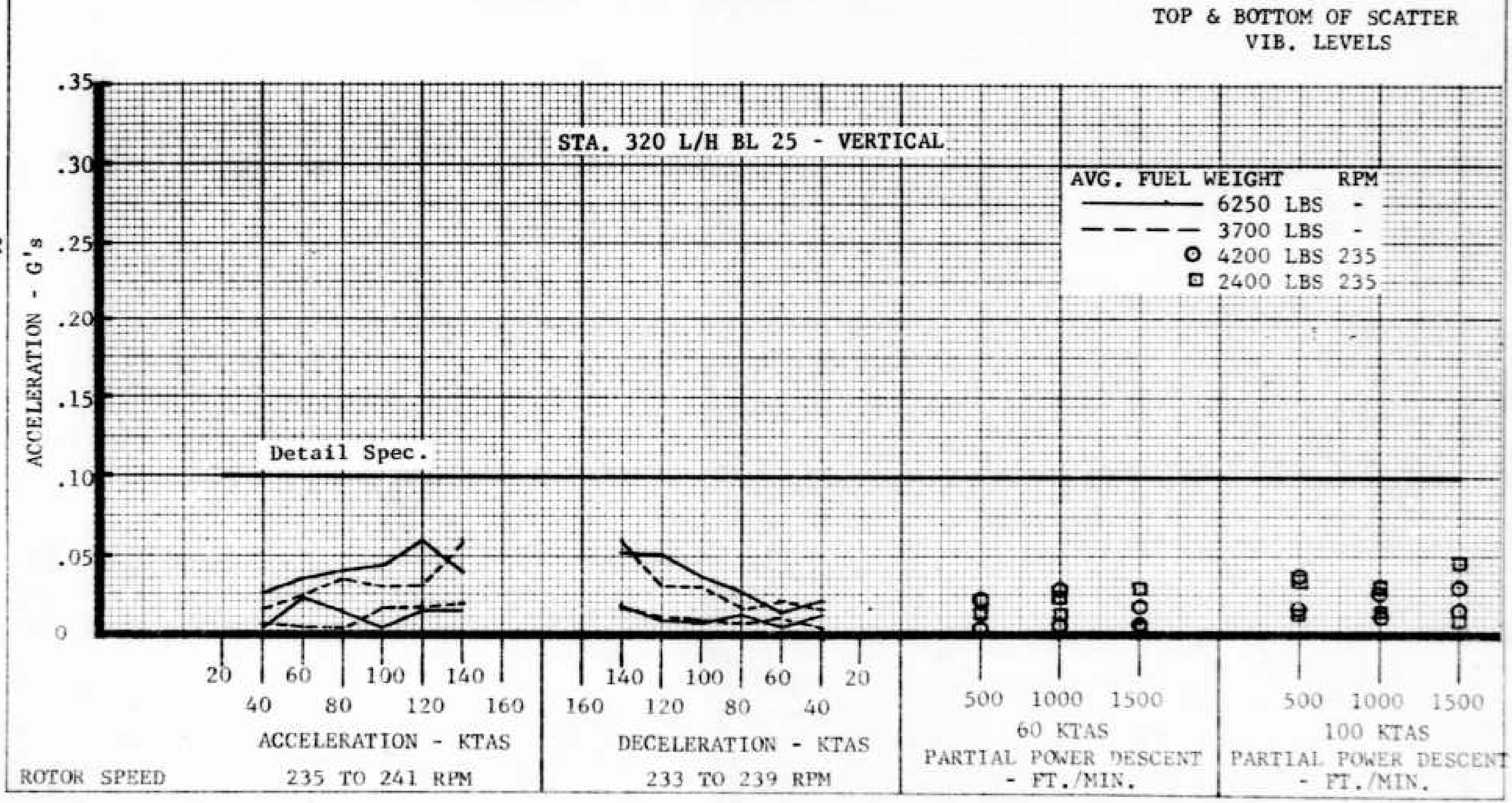


FIGURE 53
1/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
<u>MANEUVER DATA</u>

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

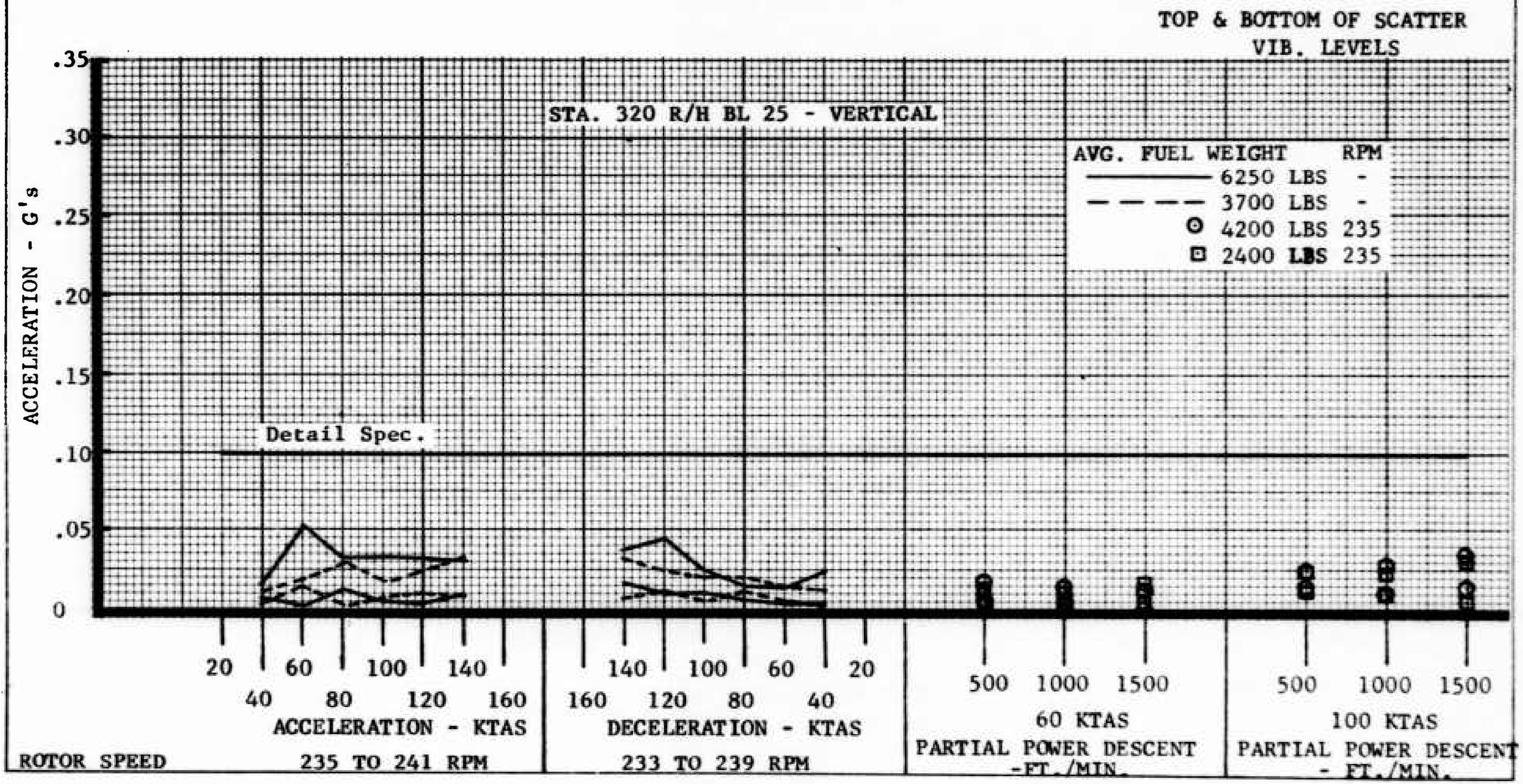


FIGURE 54
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP &LONG. CYCLIC) = AUTO

235 RPM

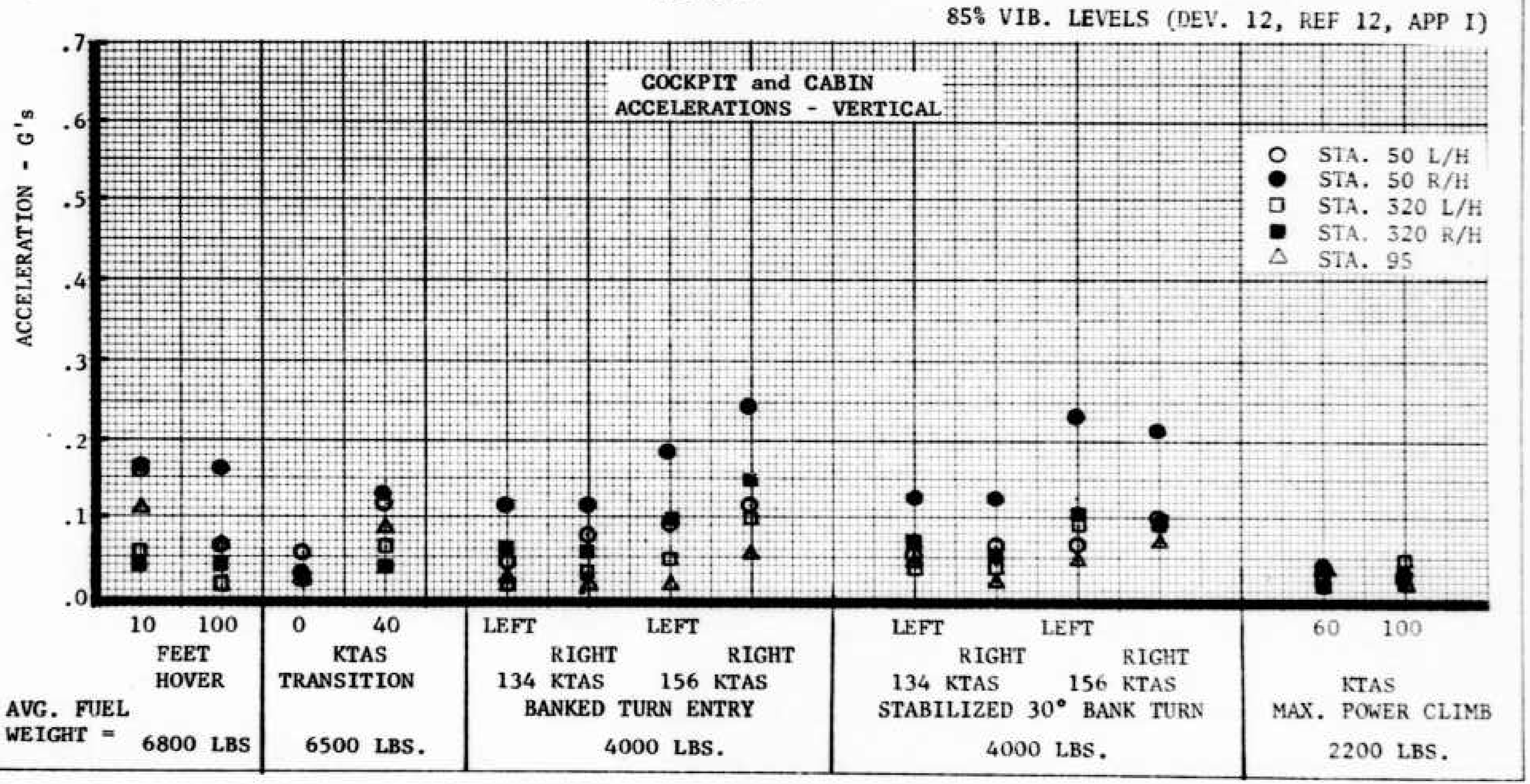


FIGURE 55
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

245 RPM

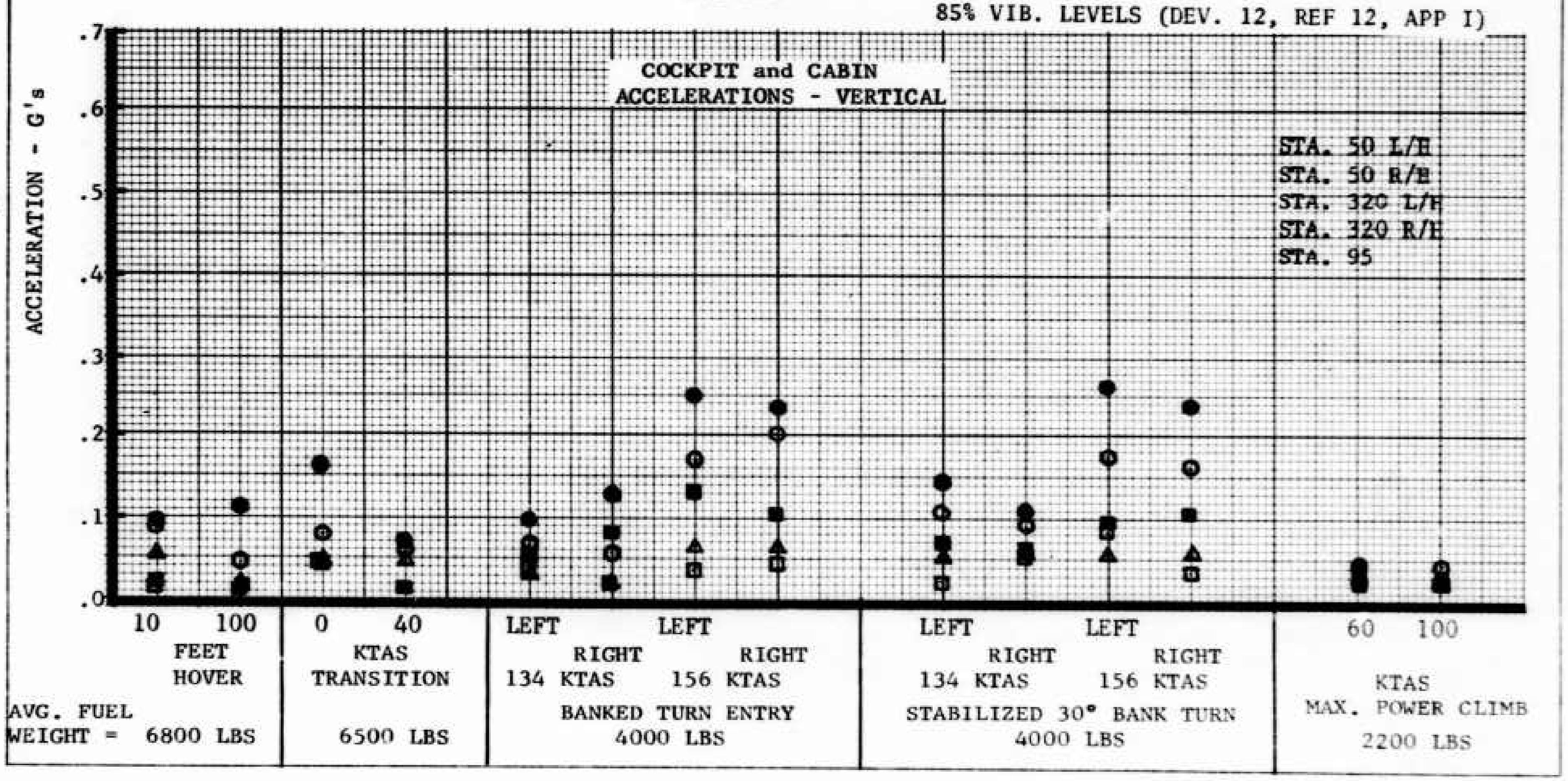


FIGURE 56
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
<u>MANEUVER DATA</u>

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

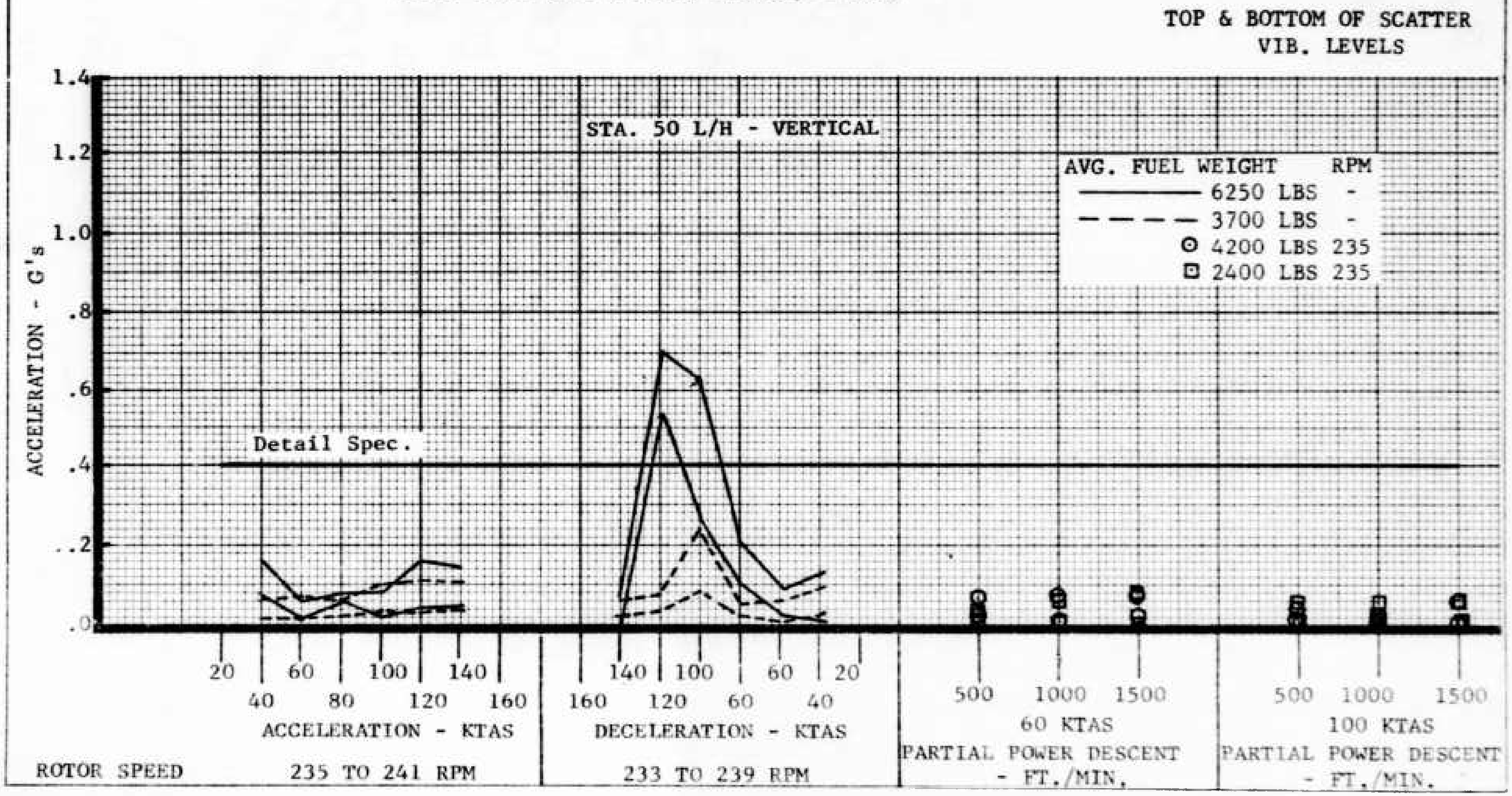


FIGURE 57
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

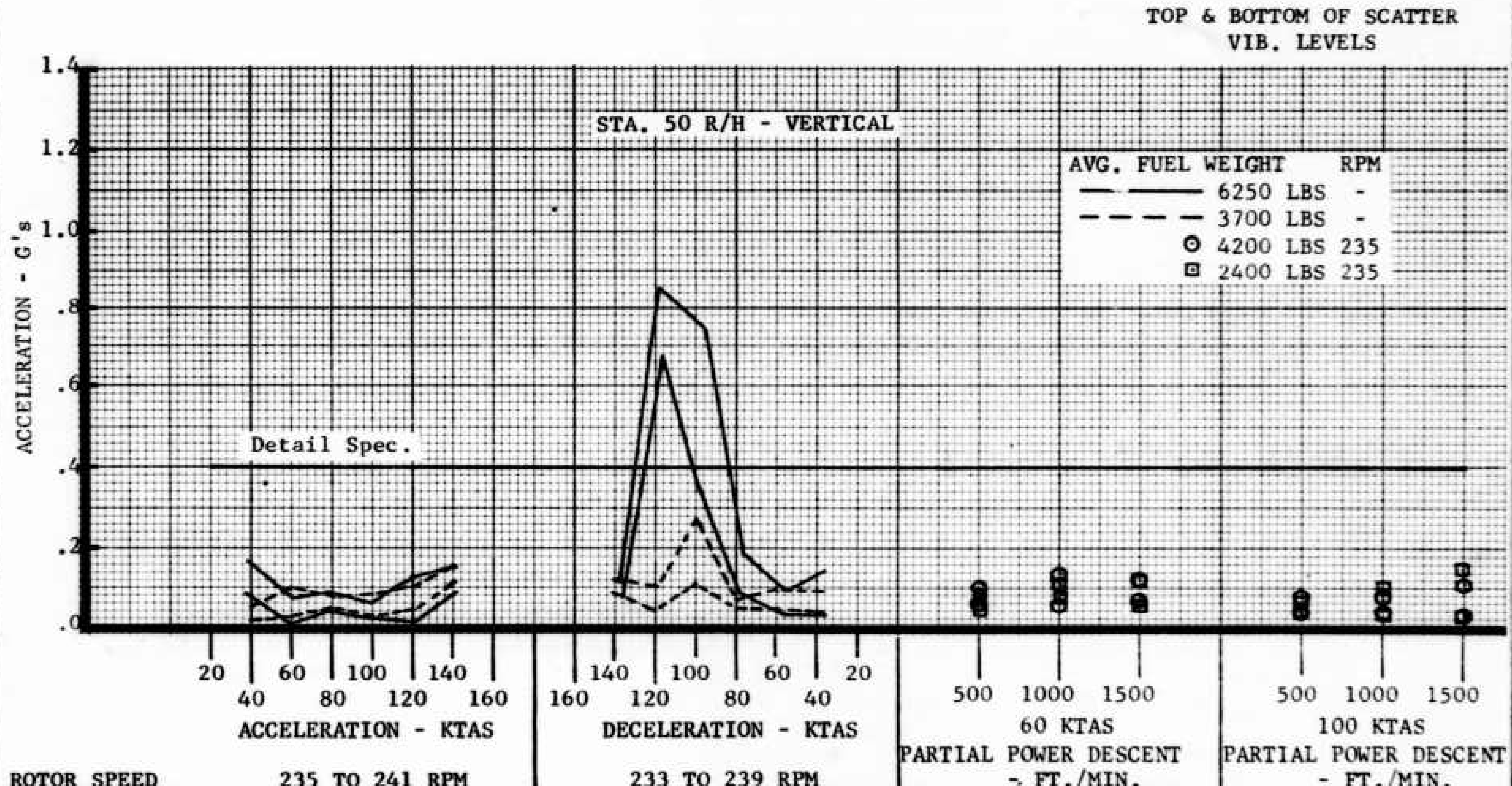


FIGURE 58
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP &LONG. CYCLIC) = AUTO

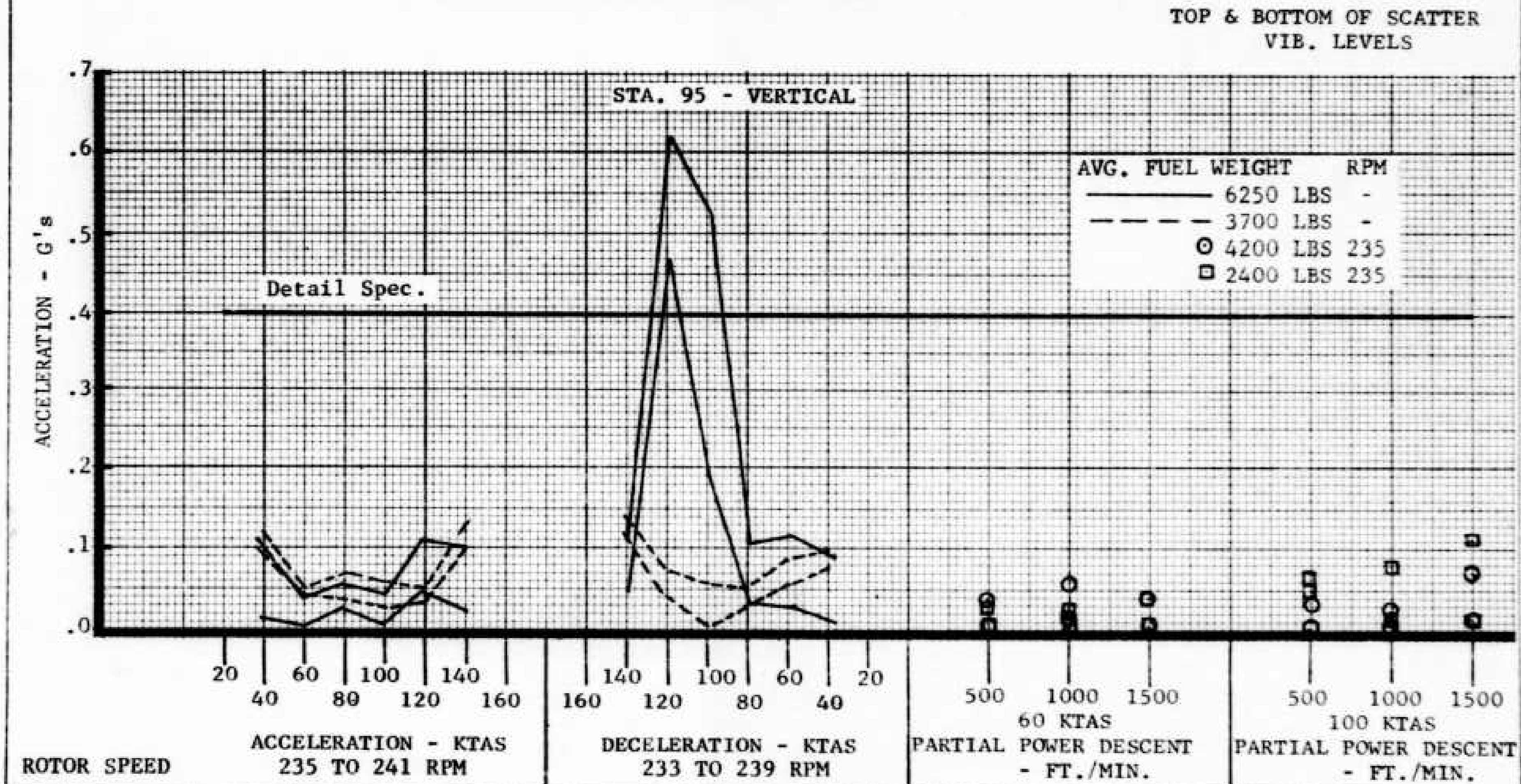


FIGURE 59

3/REV VIBRATION CHARACTERISTICS

CH-47C USA S/N 68-15858

MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

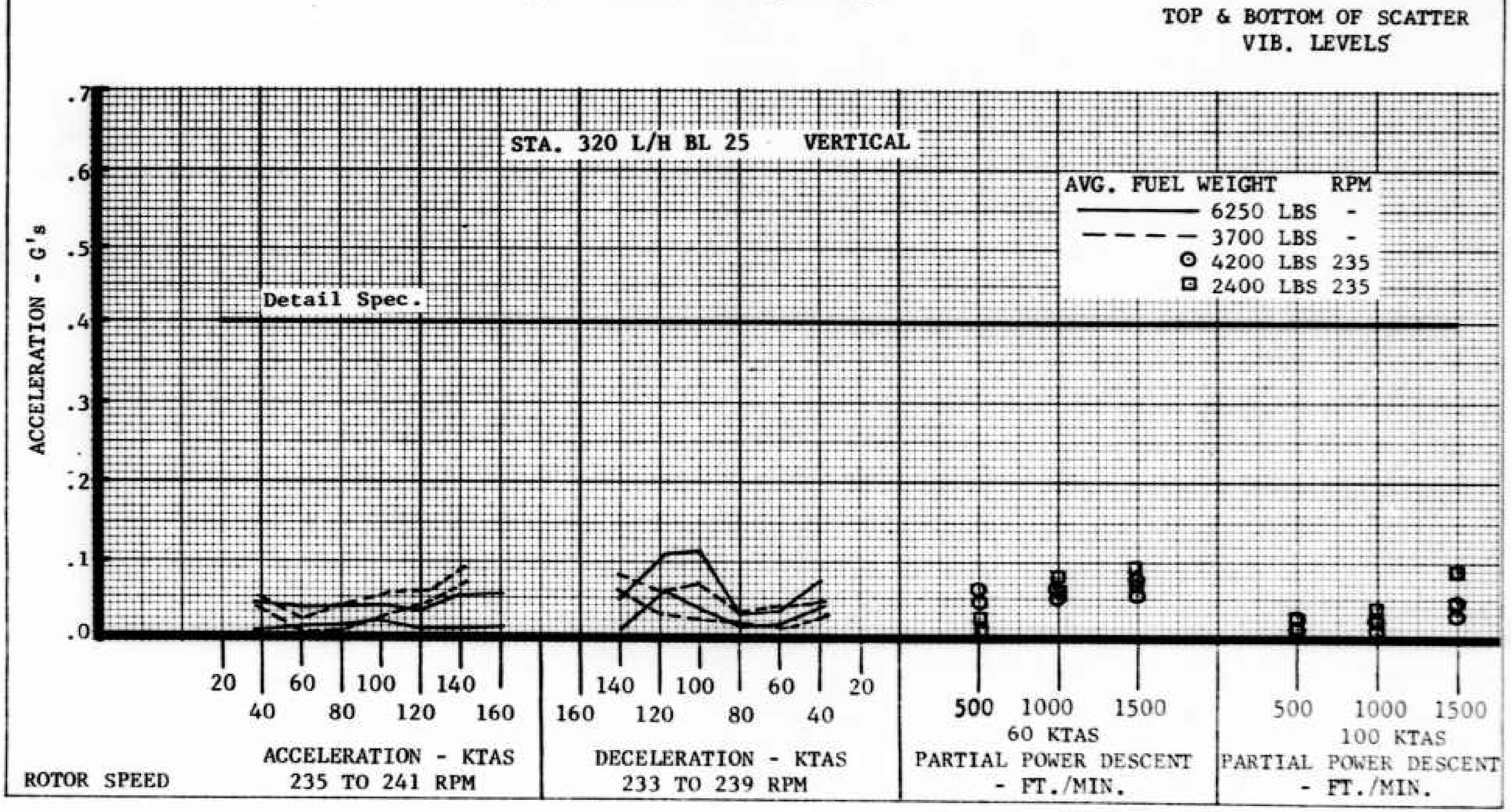


FIGURE 60
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
<u>MANEUVER DATA</u>

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 3.5" FWD
AVG. DENSITY ALTITUDE = 1300 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

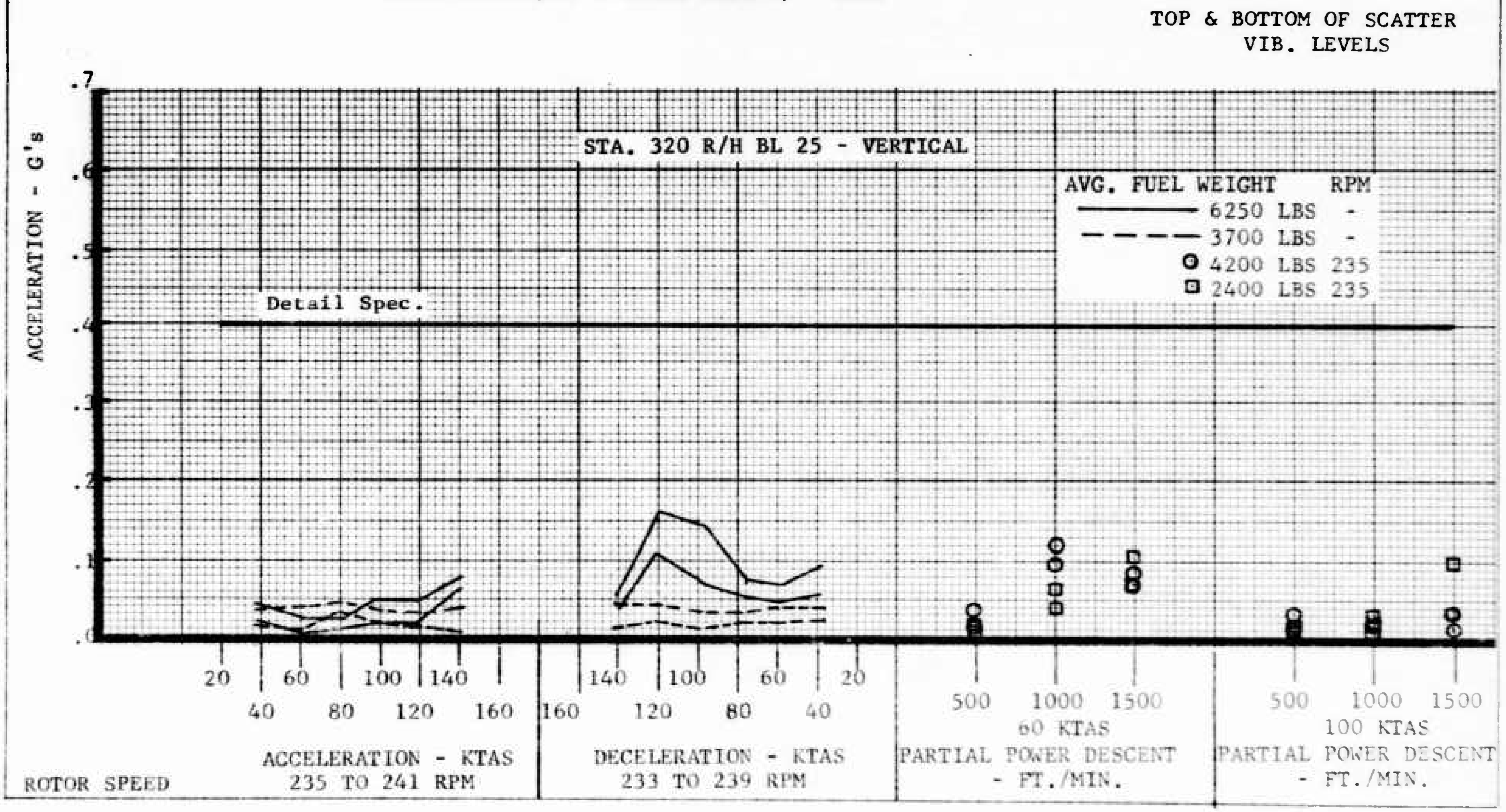


FIGURE 61

3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
TIME HISTORY - DECELERATION

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 4.4" FWD
AVG. DENSITY ALTITUDE = 700 FT.
OUTSIDE AIR TEMPERATURE = +8°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO
AVG. FUEL WEIGHT = 6200 LB.

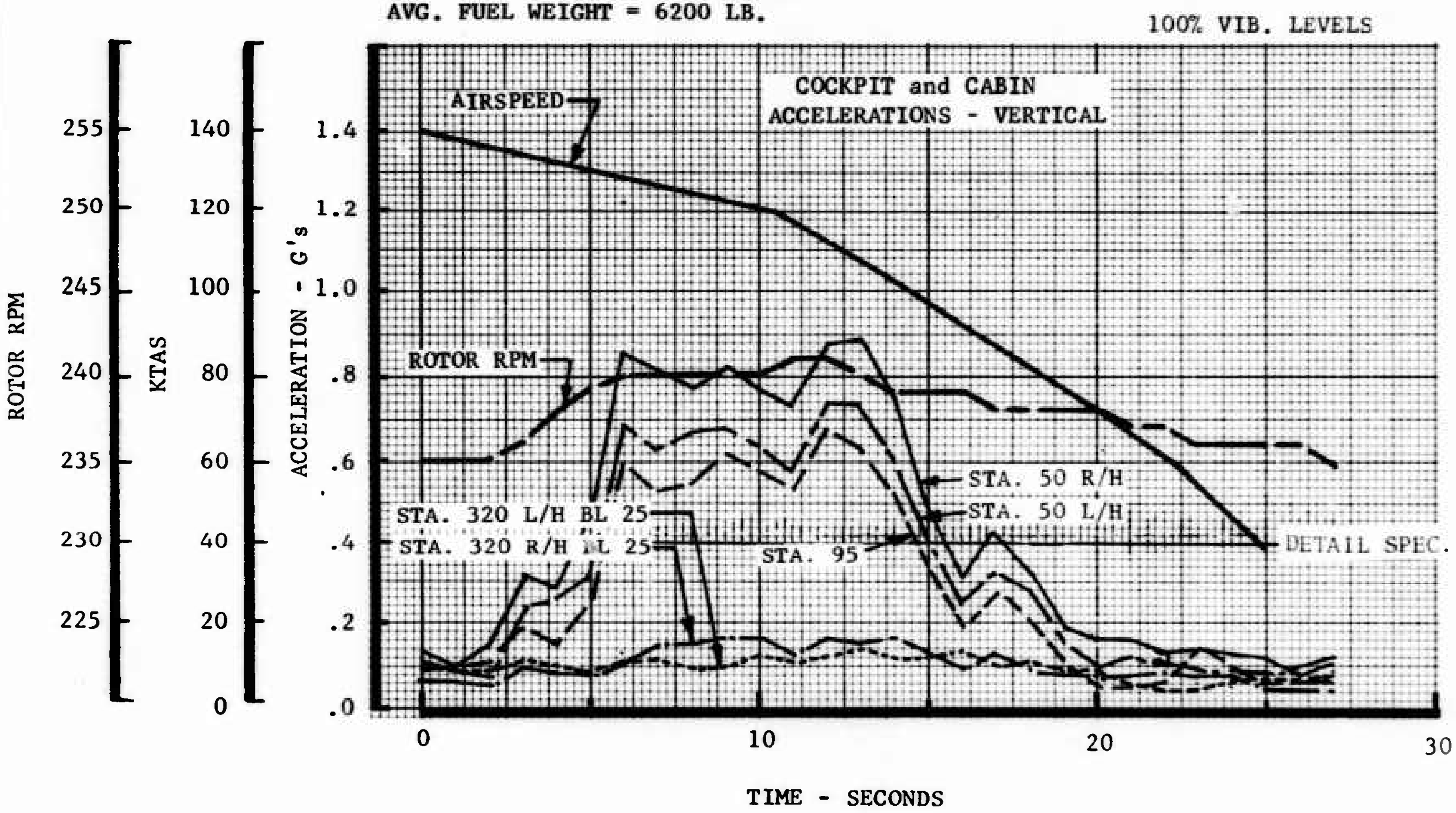


FIGURE 62

3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
TIME HISTORY - DECELERATION

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 4.1" FWD
AVG. DENSITY ALTITUDE = 1500 FT.
OUTSIDE AIR TEMPERATURE = +15°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO
AVG. FUEL WEIGHT = 3700 LB.

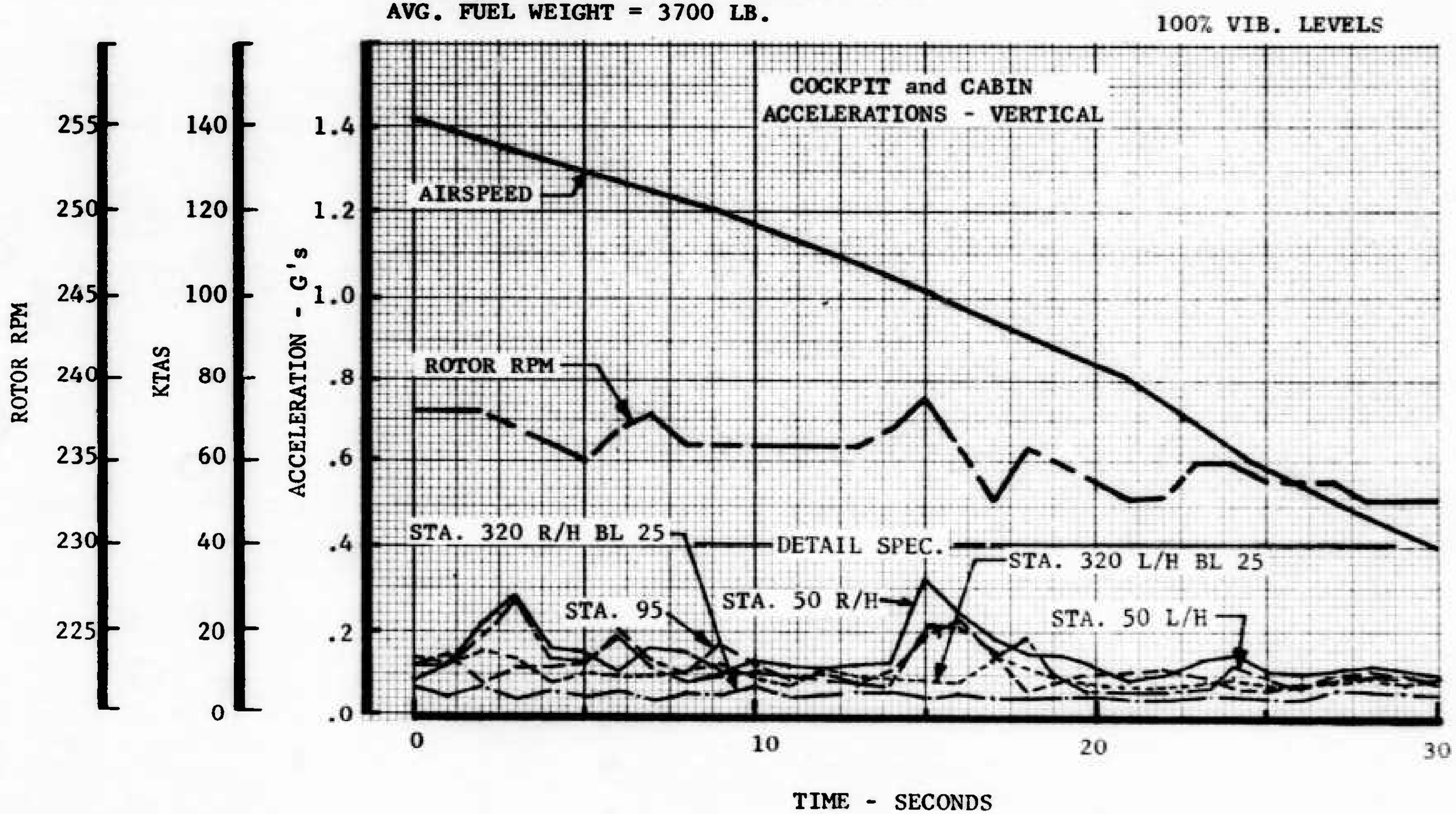


FIGURE 63
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
TIME HISTORY - DECELERATION

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 30,100 LB.
AVG. C.G. = 4.3" FWD
AVG. DENSITY ALTITUDE = 1000 FT.
OUTSIDE AIR TEMPERATURE = +10°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO
AVG. FUEL WEIGHT = 6000 LB.

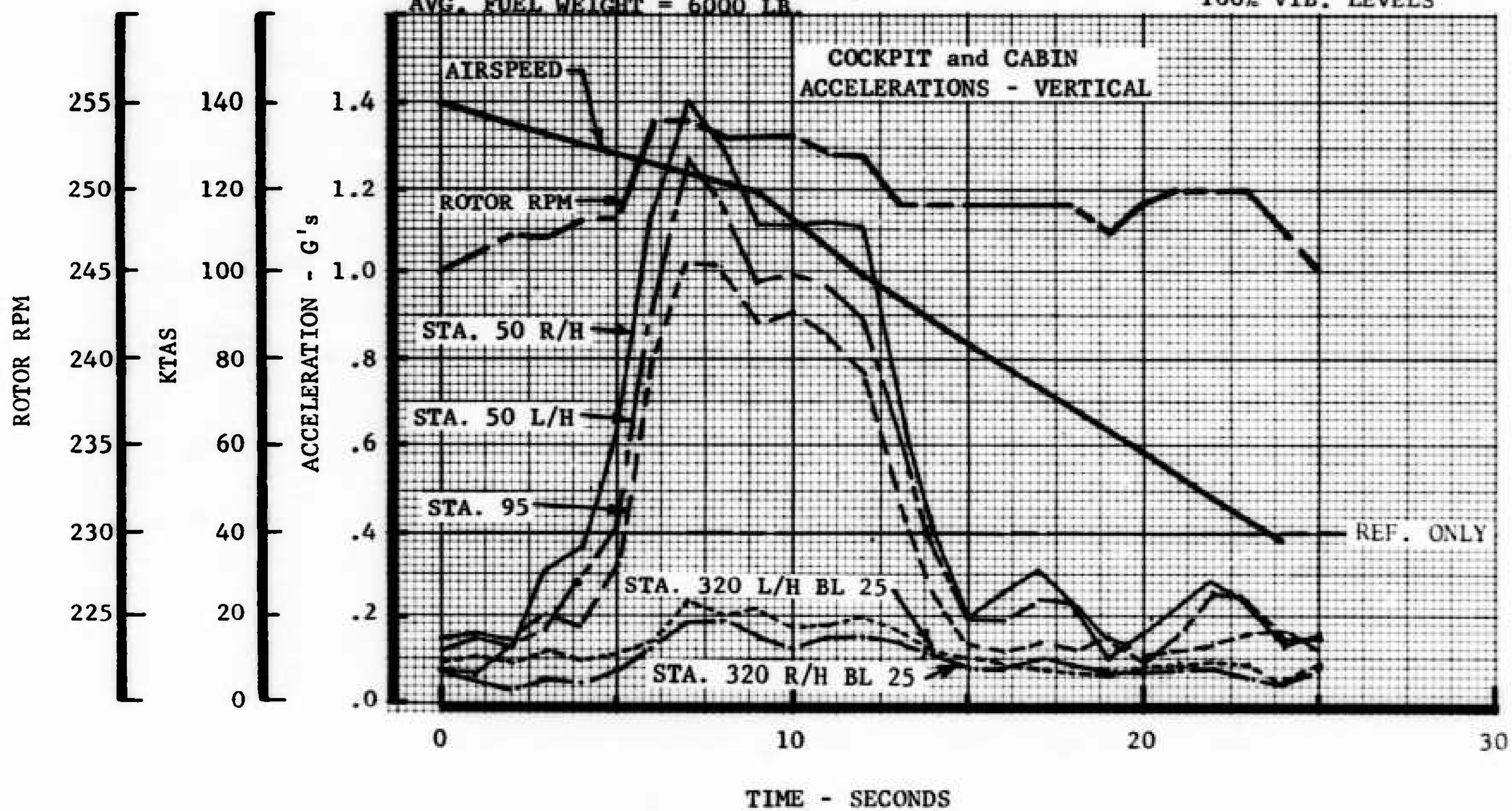


FIGURE 64

3/REV VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - 85% VIB. LEVELS *

AVG. CG = 0.2" AFT | AVG. CG = 1.1" AFT
AVG. DENSITY ALTITUDE = 2000 FT. | AVG. DENSITY ALTITUDE = 1900 FT.
OUTSIDE AIR TEMPERATURE = +4°C | OUTSIDE AIR TEMPERATURE +2°C

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 39,850 LB.
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

AVG. FUEL WEIGHT = 6600 LB. | AVG. FUEL WEIGHT = 4400 LB.

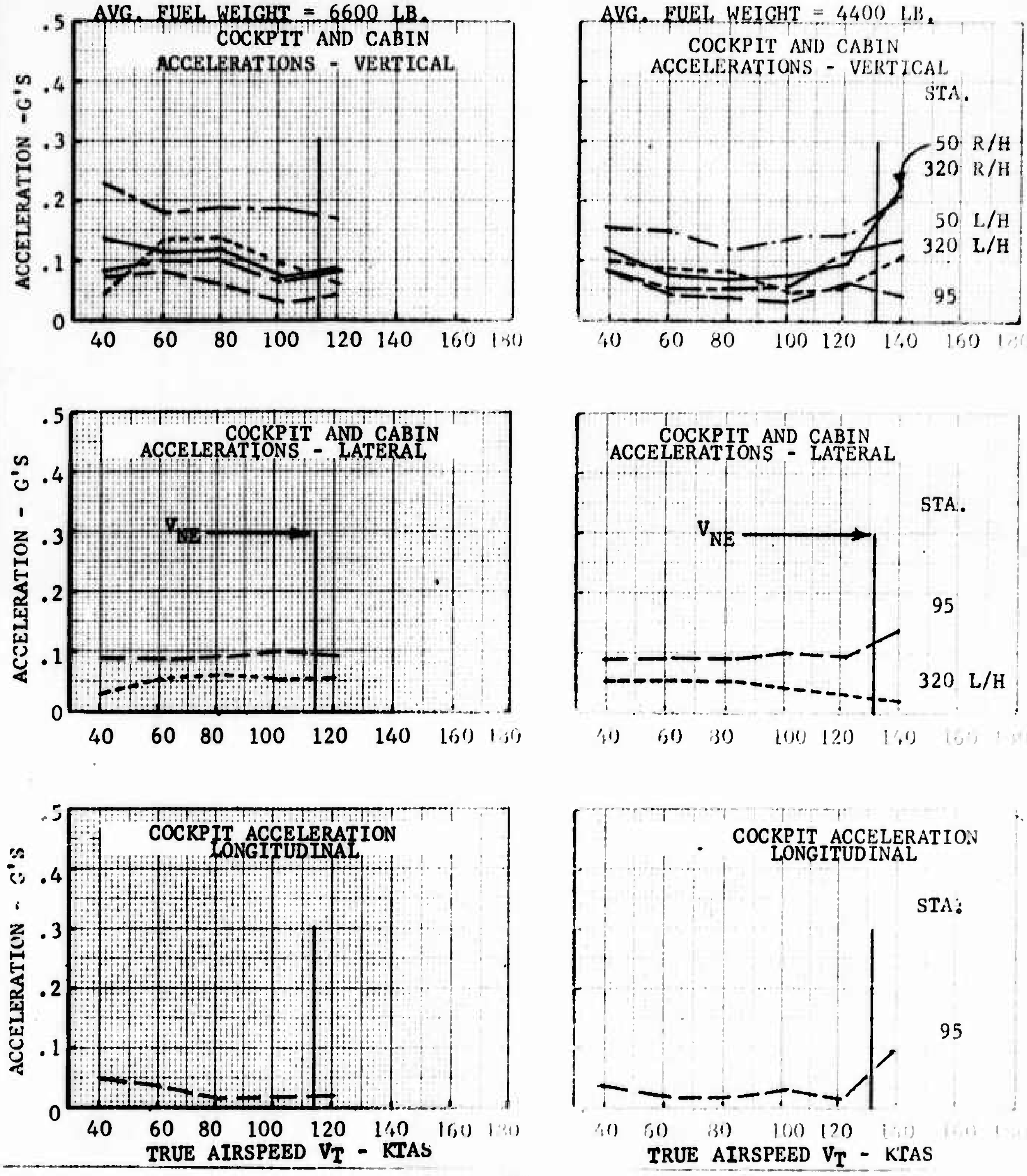


FIGURE 65
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 39850 LB.
AVG. C.G. = 0.4" AFT
AVG. DENSITY ALTITUDE = 1700 FT.
OUTSIDE AIR TEMPERATURE = +4°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

242 TO 246 RPM

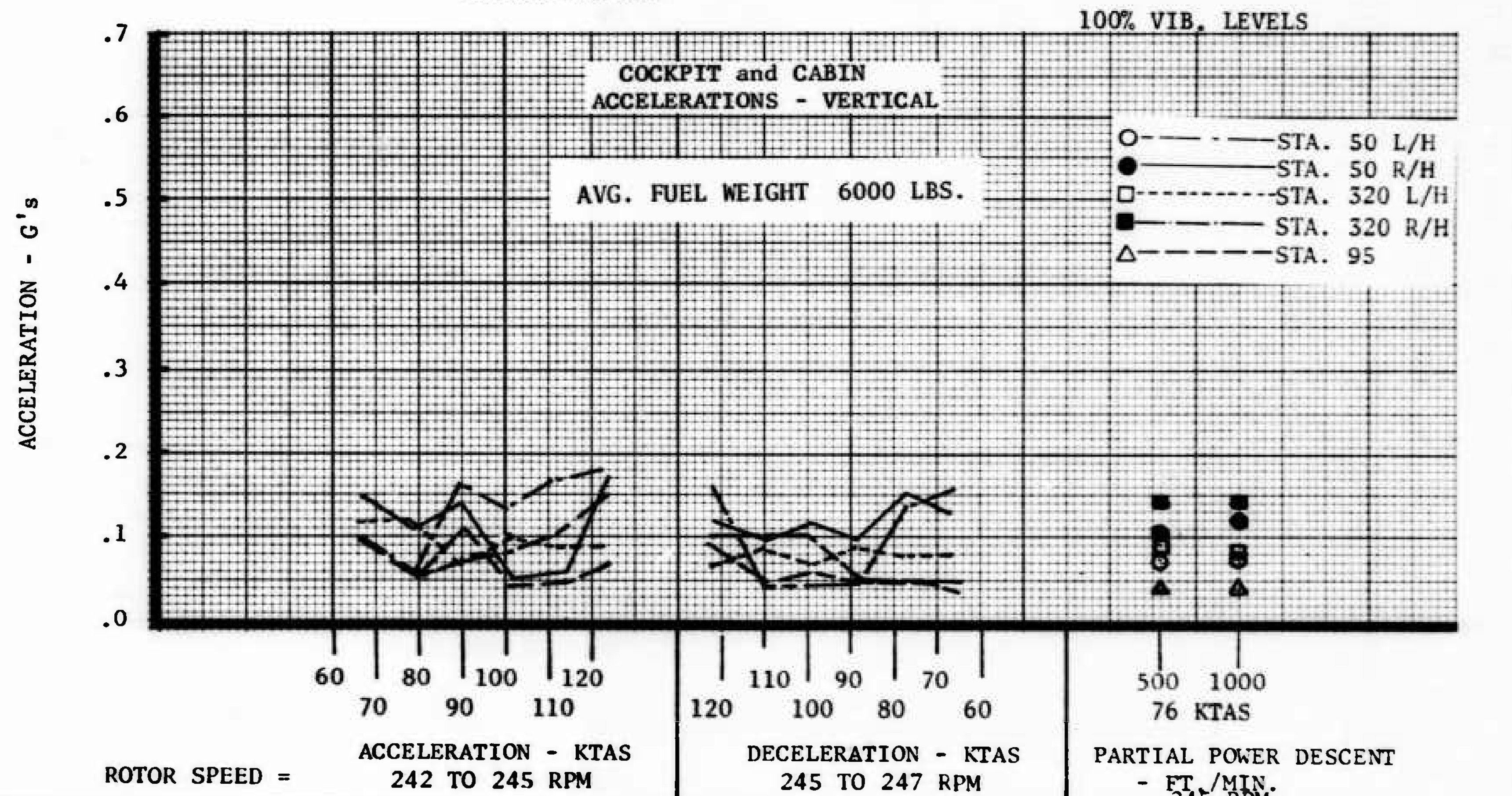


FIGURE 66
3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
MANEUVER DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 39,850 LB.
AVG. C.G. = 0.5" AFT
AVG. DENSITY ALTITUDE = 1800 FT.
OUTSIDE AIR TEMPERATURE = ± 5°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

245 RPM

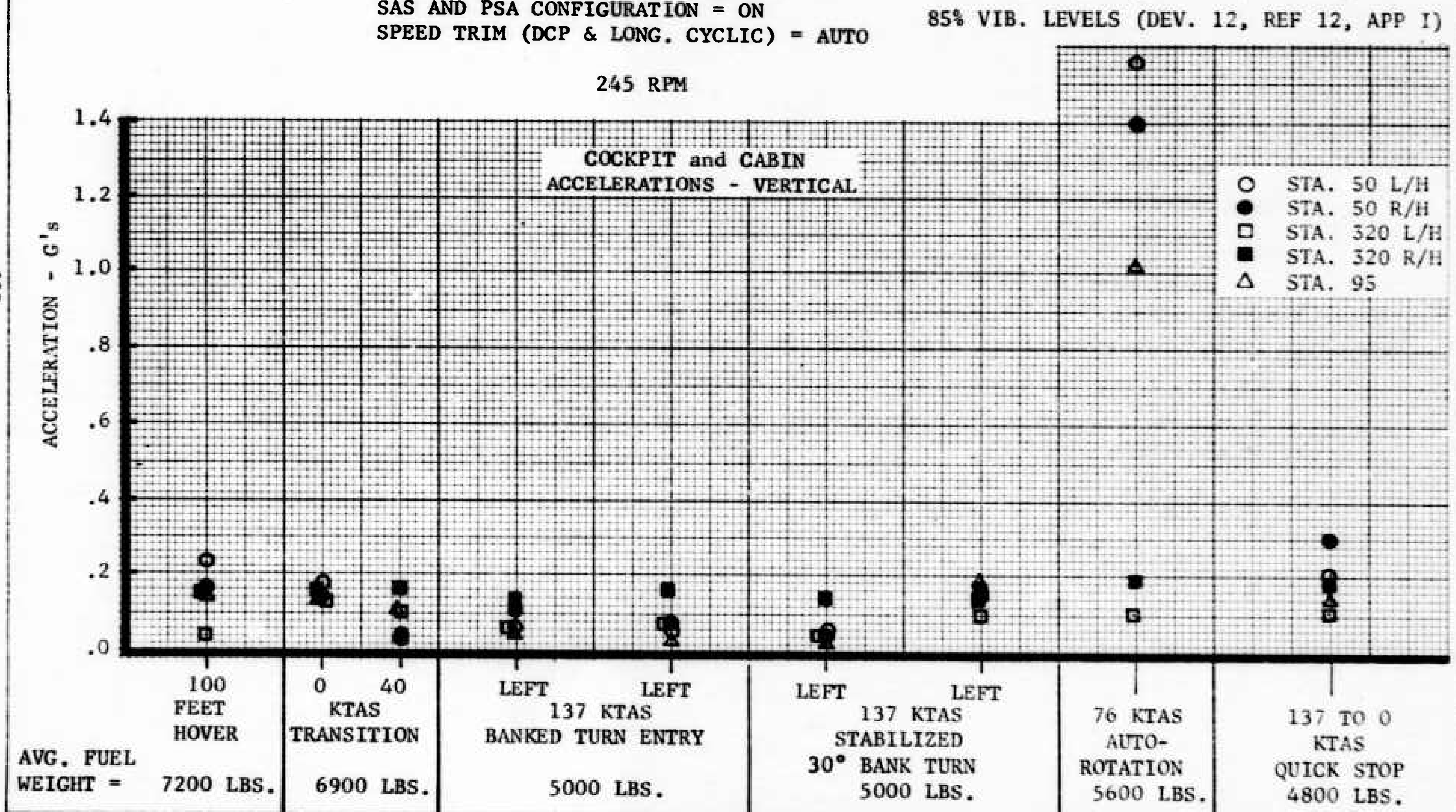


FIGURE 67

3/REV VIBRATION CHARACTERISTICS
CH-47C, USA S/N 68-15858
TIME HISTORY - AUTOROTATION

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 39,850 LB.
AVG. C.G. = 0.6" AFT
AVG. DENSITY ALTITUDE = 1500 FT.
SAS AND PSA CONFIGURATION = ON
OUTSIDE AIR TEMPERATURE = +2°C
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO
AVG. FUEL WEIGHT = 5500 LB.

AIRSPEED = 76 KTAS

100% VIB. LEVELS

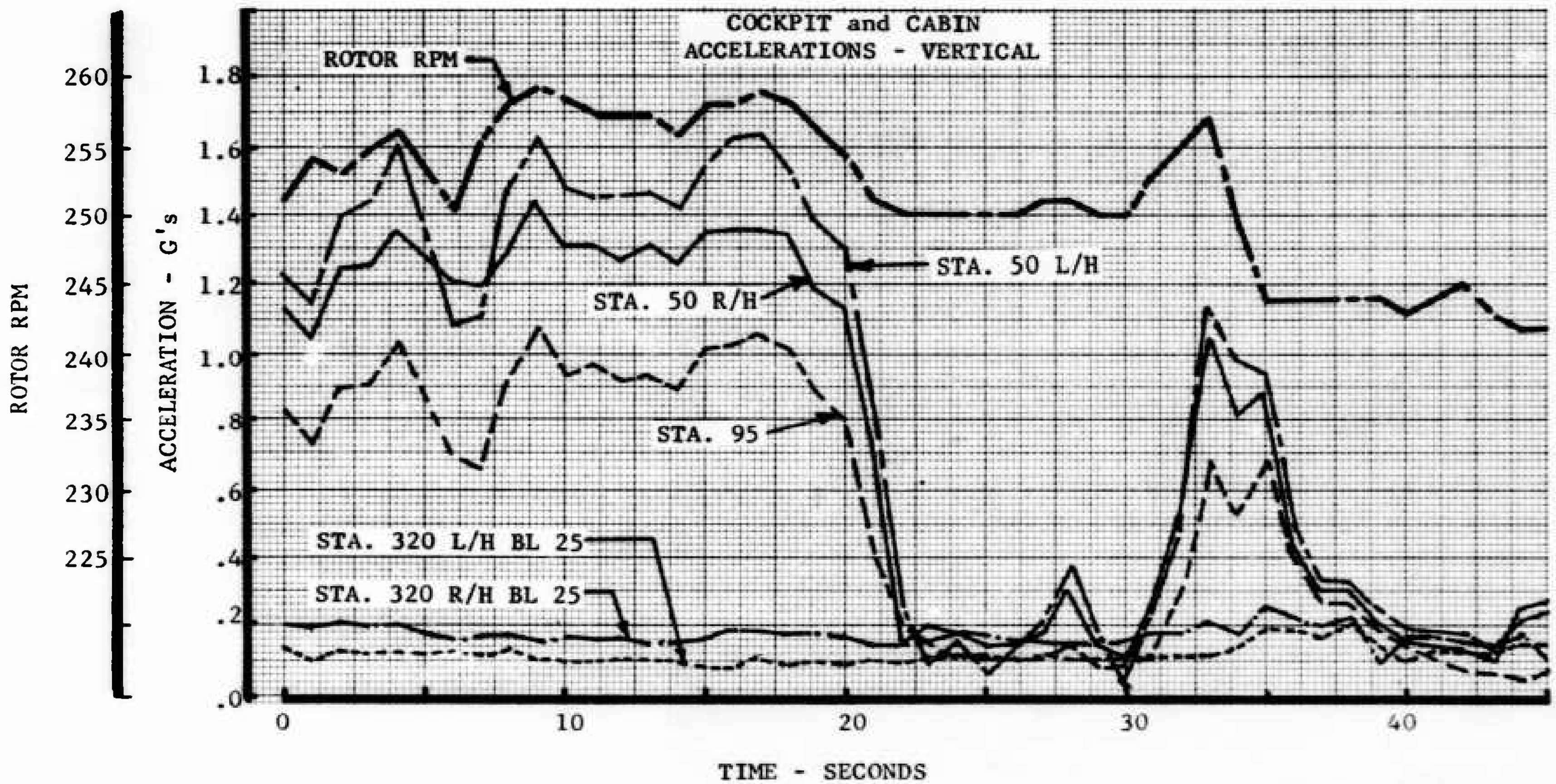


FIGURE 68

PRODUCTION ACCEPTANCE VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - VADI DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 21,100 LB.
AVG. C.G. = 4.0" AFT
AVG. DENSITY ALTITUDE = 1200 FT.
OUTSIDE AIR TEMPERATURE = -1°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

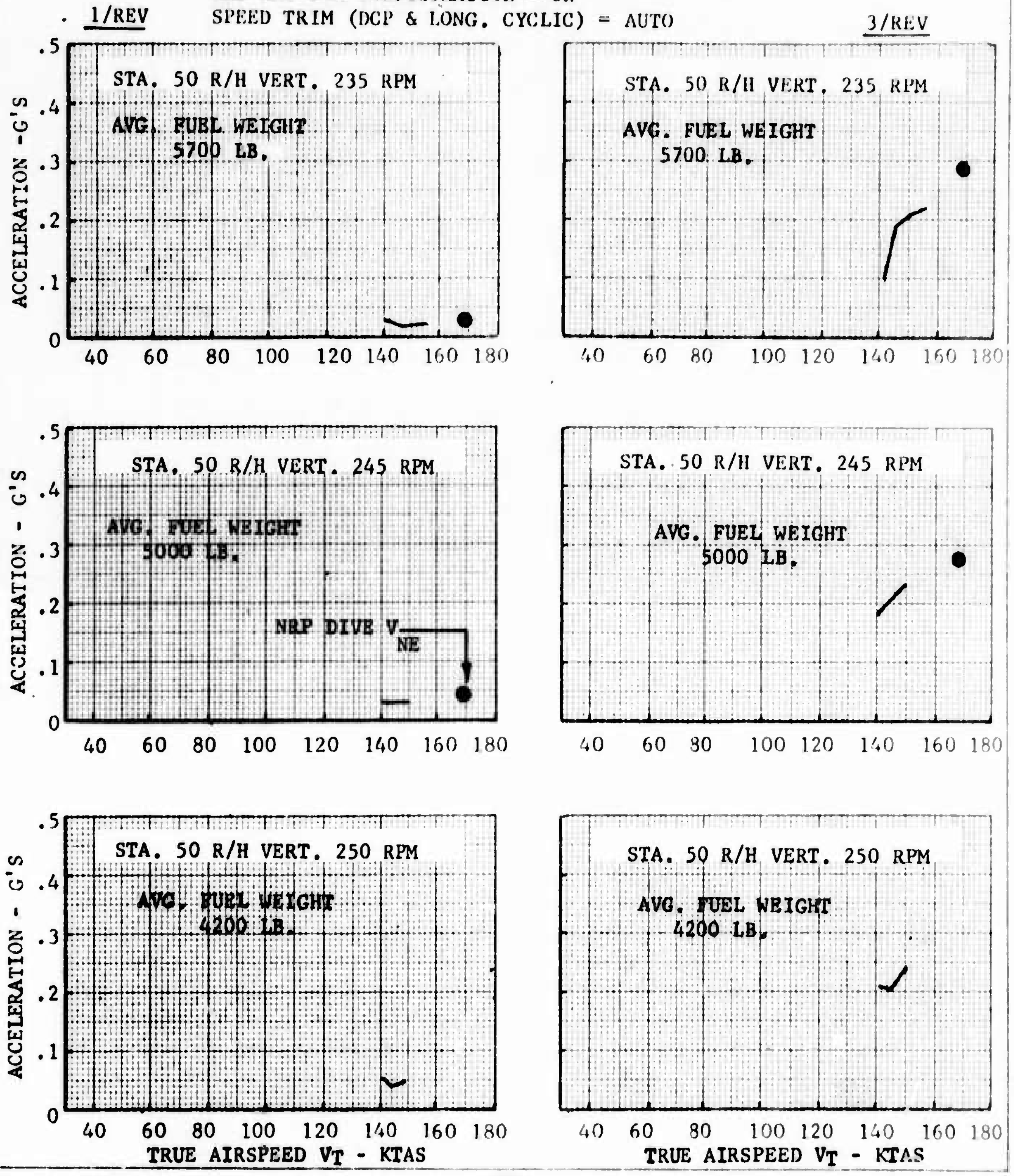


FIGURE 69

PRODUCTION ACCEPTANCE VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - VADI DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 21,100 LB.
AVG. C.G. = 4.0" AFT
AVG. DENSITY ALTITUDE = 1200 FT.
OUTSIDE AIR TEMPERATURE = .1°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

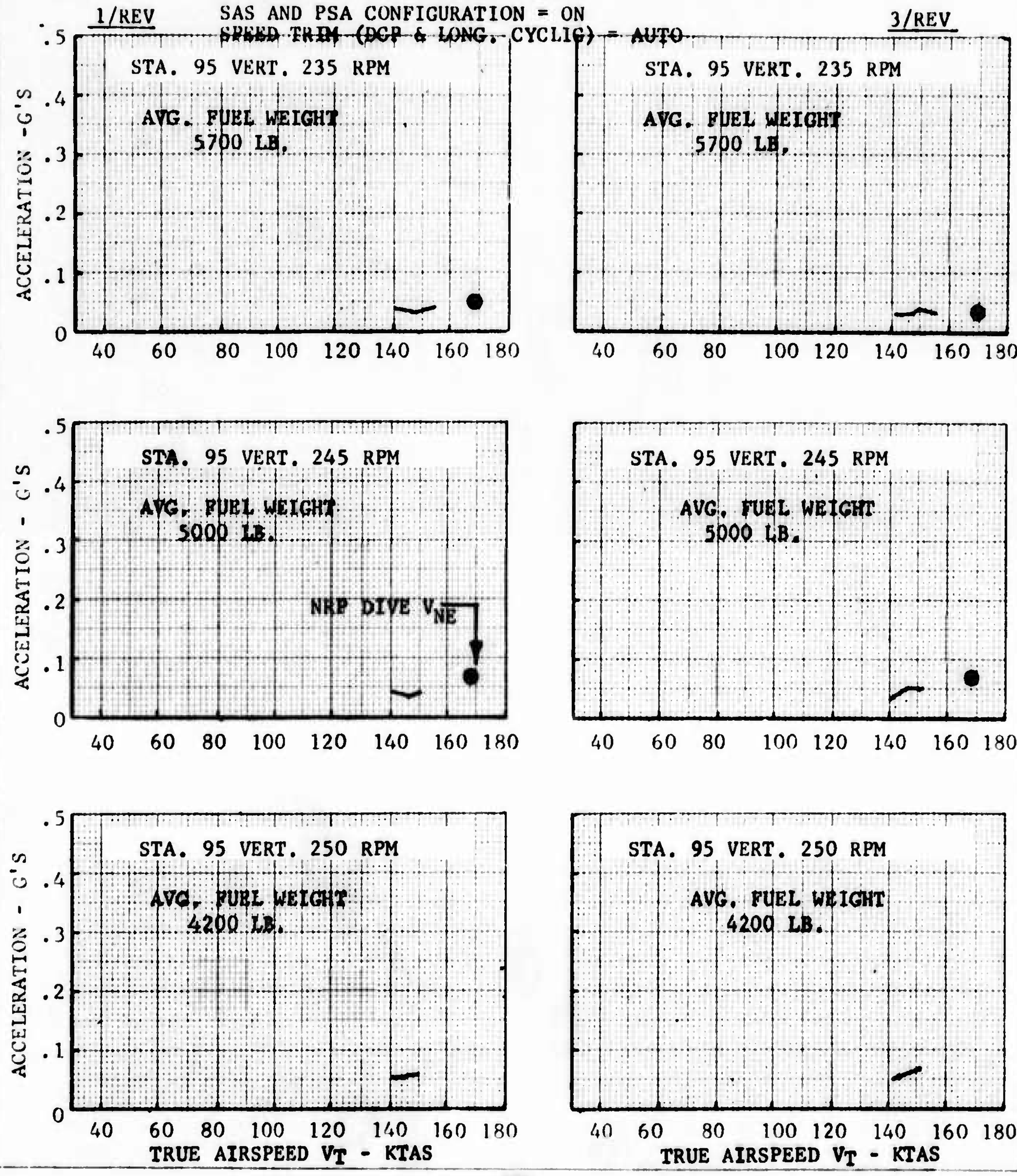


FIGURE 70

PRODUCTION ACCEPTANCE VIBRATION CHARACTERISTICS
CH-47C USA S/N 68-15858
LEVEL FLIGHT - VADI DATA

AIRCRAFT GROSS WEIGHT (LESS FUEL) = 21,100 LB.
AVG. C.G. = 4.0" AFT
AVG. DENSITY ALTITUDE = 1200 FT.
OUTSIDE AIR TEMPERATURE = -1°C
SAS AND PSA CONFIGURATION = ON
SPEED TRIM (DCP & LONG. CYCLIC) = AUTO

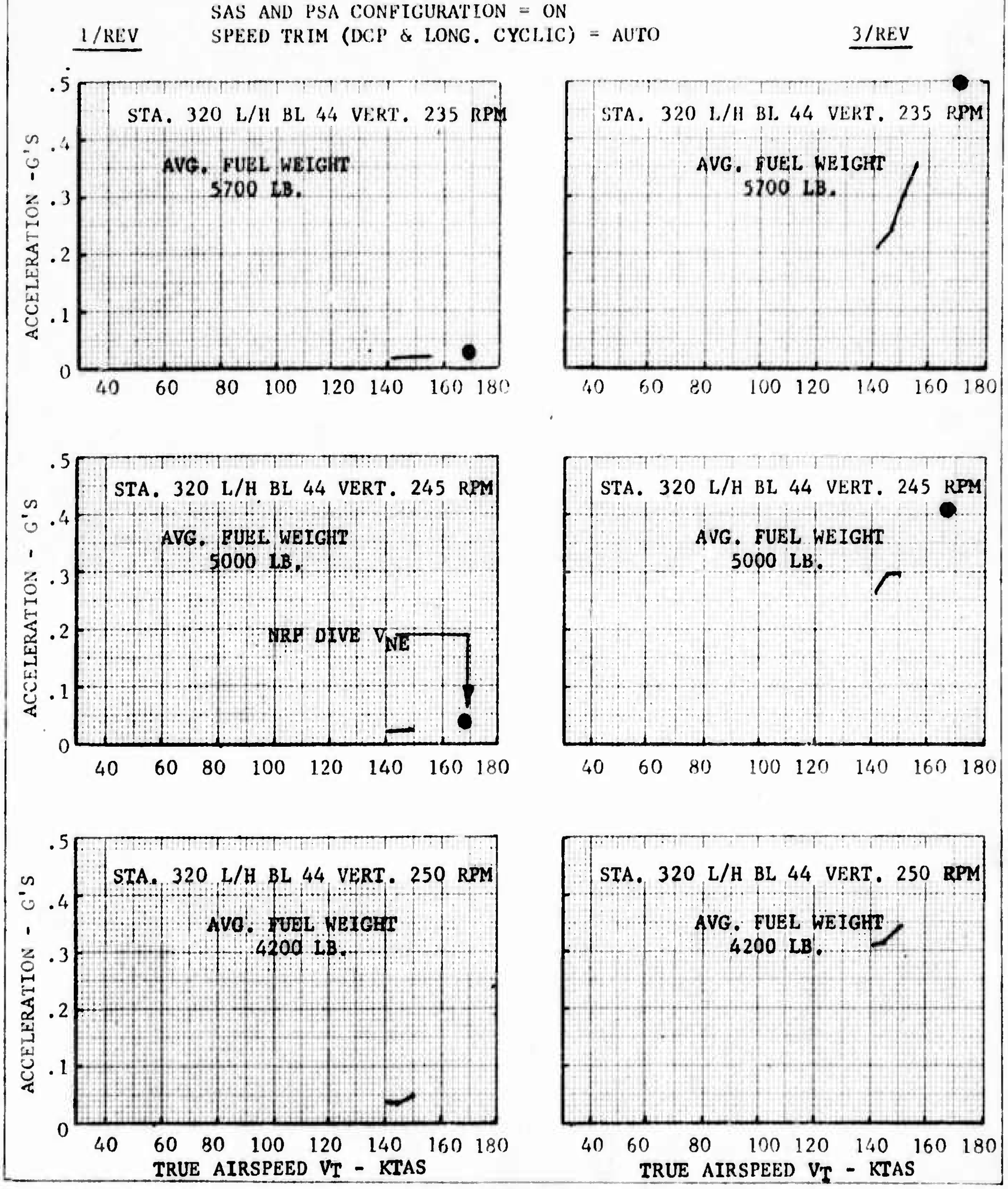
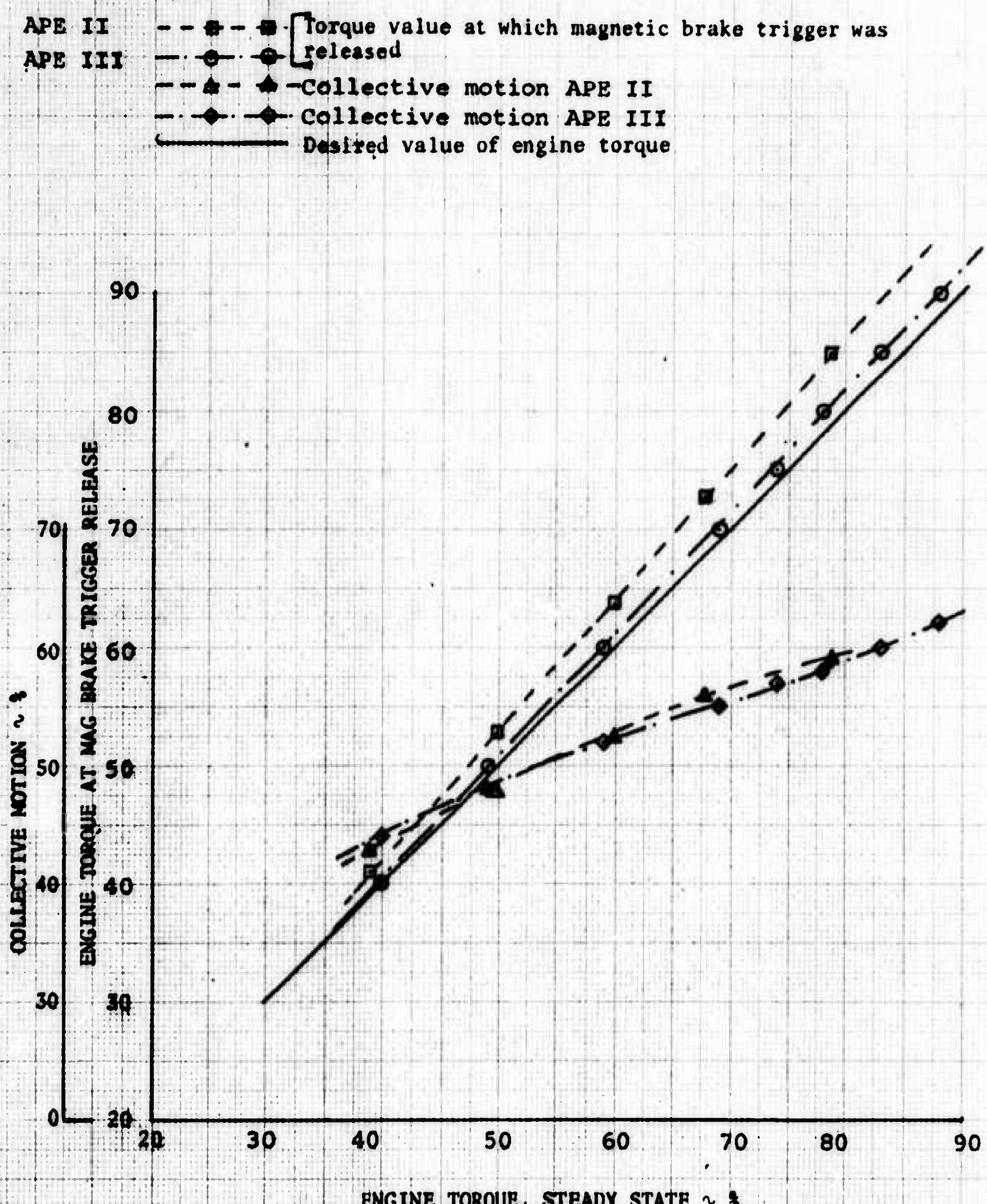


FIGURE 71
THRUST ROD/TORQUE CONTROL CHARACTERISTICS
YCH-47C USA S/N 66-19121

ROTOR SPEED 245 RPM



APPENDIX III. TEST INSTRUMENTATION

1. APE III test instrumentation for the YCH-47C, S/N 66-19121, (Tab No. B-379) are as follows.

Parameter	Mag Tape	Cockpit	Photopanel
Rotor rpm indicator	X[1]	S[2]	C[3]
No. 1 engine N_1	X	C	C
No. 2 engine N_1	X	C	C
No. 1. engine fuel flow	X	-[4]	C
No. 2 engine fuel flow	X	-	C
Sideslip angle	X	C	C
O.A.T.	X	S	C
Forward cyclic trim	X	C	C
Aft cyclic trim	X	C	C
Boom airspeed	X	S	C
Ship's airspeed	X	C	C
Boom altitude	X	C	C
Ship's altitude	X	C	C
Torquemeter	X	C	C
No. 1 engine fuel temperature	X	-	C
No. 2 engine fuel temperature	X	-	C
One-per-revolution forward green at 180 degrees	X	-	-
One-per-revolution aft green at 180 degrees	X	-	-
Accelerometers:			
FS 95 center, lateral	X	-	-
FS 320 right, BL 48, vertical	X	-	-
FS 95 center, vertical	X	-	-
No. 1 SAS pitch position	X	-	-
No. 2 SAS pitch position	X	-	-
Lateral stick position	X	S	-
Yaw attitude	X	-	-
Directional pedal position	X	S	-
No. 2 SAS yaw position	X	-	-
Yaw rate	X	-	-
Yaw angular acceleration[5]	X	-	-
Thrust control rod position	X	S	-
No. 1 SAS yaw position	X	-	-
Roll rate	X	-	-
Roll angular acceleration[5]	X	-	-
Pitch rate	X	-	-
Pitch angular acceleration[5]	X	-	-

See footnotes at end of appendix III, page 114.

Parameter	Mag Tape	Cockpit	Photopanel
Longitudinal stick position	X	-	-
DCP speed trim actuator position	X	X	-
No. 2 SAS roll position	X	-	-
Attitude, airspeed signal to DCP	X	-	-
Roll attitude	X	-	-
Pitch attitude	X	-	-
No. 1 SAS roll position	X	-	-
DCP speed trim motor voltmeter signal	X	-	-

2. APE III test instrumentation for CH-47C, S/N 68-15812, (Tab No. B-524) are as follows:

Parameter	Mag Tape	Cockpit	Photopanel
Rotor rpm indicator	X	C	-
Ship's airspeed	X	C	C
Ship's altitude	X	C	C
O.A.T.	X	-	-
Accelerometers:			
FS 50 left, vertical	X	-	-
FS 50 right, vertical	X	-	-
Pilot's right vertical heel slide	X	-	-
Pilot's center panel vertical stick	X	-	-
Copilot's center panel vertical stick	X	-	-
Pilot's vertical cyclic	X	-	-
Pilot's longitudinal cyclic	X	-	-
Copilot's lateral cyclic	X	-	-
Copilot's longitudinal cyclic	X	-	-
Pilot's right longitudinal pedal	X	-	-
Copilot's right longitudinal pedal	X	-	-
FS 95 center, vertical	X	-	-
FS 95 center, vertical	X	-	-
FS 95 center, longitudinal	X	-	-
FS 320 left, BL 25, vertical	X	-	-
FS 320 left, BL 25, lateral	X	-	-
FS 320 right, BL 25, vertical	X	-	-
FS 320 left, BL 44, vertical	X	-	-
Copilot's right vertical heel slide	X	-	-

VADI Installations

X36, FS 95 center, vertical; FS 320 right, BL 25, vertical
X46, FS 95 center, vertical; FS 320 left, BL 44, vertical
X48, FS 95 center, vertical; FS 320 left, BL 44, vertical
X49, FS 95 center, vertical; FS 320 left, BL 44, vertical
X52, FS 95 center, vertical; FS 50 right, BL 30, vertical

3. APE IV test instrumentation for CH-47C, S/N 68-15858, (Tab No. B-570) are as follows:

Parameter	Mag Tape	Cockpit	Photopanel
Rotor rpm indicator	X	C	-
Ship's airspeed	X	C	-
Ship's altitude	X	C	-
O.A.T.	X	C	-
No. 1 engine torque	X	C	-
No. 2 engine torque	X	C	-
No. 1 engine fuel flow	X	-	-
No. 2 engine fuel flow	X	-	-
One-per-revolution forward yellow blade at zero degrees	X	-	-
One-per-revolution aft yellow blade at zero degrees	X	-	-
Accelerometers:			
Copilot's longitudinal cyclic stick	X	-	-
Copilot's lateral cyclic stick	X	-	-
FS 50 right, vertical	X	-	-
FS 320 left, BL 44, vertical	X	-	-
FS 320 left, BL 25, vertical	X	-	-
FS 320 right, BL 25, vertical	X	-	-
FS 320 left, BL 25, lateral	X	-	-
FS 95 left, vertical	X	-	-
FS 50 left, vertical	X	-	-
FS 95 center, lateral	X	-	-
FS 95 center, longitudinal	X	-	-
FS 482 right, BL 44, vertical	X	-	-
FS 570 center thrust deck, vertical	X	-	-
FS 339 right main tank, vertical	X	-	-
FS 413 right aft auxiliary tank, vertical	X	-	-
Copilot's vertical center panel	X	-	-

Parameter	Mag Tape	Cockpit	Photopanel
Pilot's vertical center panel	X	-	-
Pilot's right longitudinal pedal	X	-	-
Copilot's right longitudinal pedal	X	-	-
Pilot's right vertical heel slide	X	-	-
Copilot's right vertical heel slide	X	-	-
Pilot's vertical cyclic	X	-	-
Pilot's longitudinal cyclic	X	-	-

VADI Installations

All flights: FS 95 center, vertical; FS 50 right, BL 30, vertical
FS 320, BL 44, vertical

[1]X = recorded parameter.
[2]S = sensitive.
[3]C = calibrated.
[4]- = not applicable.
[5]Angular accelerations were obtained by differentiating angular rate signals electronically.

APPENDIX IV. TEST HELICOPTER CONFIGURATION

1. The test helicopter (B-379) used for the stability and control evaluation was basically configured as a production CH-47C as stated in the detail specification (ref 5, app I) except for the nonstandard items installed as described in references 6 and 7, appendix I. Between APE II and III, the test helicopter had the functions of the following ECP's incorporated:

ECP	Subject
598	Revise forward rotor longitudinal cyclic trim
599	Nose post beefup
610	Add balance springs to collective and directional control systems
611R1	Improve longitudinal stability
620	Improve roll axis controllability

2. The test helicopter (B-524) used for the vibration evaluation during APE III was basically configured as a production CH-47C as stated in the detail specification (ref 5, app 10). Additionally, the test aircraft had the functions of the following ECP's incorporated:

ECP	Subject
598	Revise forward rotor longitudinal cyclic trim (except pressure bias)
599	Nose post beefup

3. The following nonstandard items were installed prior to APE III:

   a. VADI equipment.

   b. Central instrumentation table.

4. Photographs of the instrumentation table and the VADI equipment are included in appendix VI.

5. The test helicopter (B-570) used for vibration testing during APE IV was configured as a production CH-47C as stated in the revised

detail specification, reference 12, appendix I. The following non-standard items were installed prior to APE IV:

a. VADI equipment.

b. Central instrumentation table.

6. Photographs of the instrumentation table and the VADI equipment are included in appendix VI.

APPENDIX V. PHYSICAL CHARACTERISTICS OF THE CH-47C

AREAS

1. Rotor blade area (6 at 63.1 sq ft).	379 sq ft
2. Projected disc area.	5,655 sq ft
3. Swept disc area (2 rotors at 2,827 sq ft used in performance calculations).	5,000 sq ft

DIMENSIONS AND GENERAL DATA

1. Rotor spacing (distance between center line of rotors).	39 ft, 2 in.
2. Height (over rotor blades at rest).	18 ft, 7.1 in.
3. Sail area (cross-section area of aircraft at butt line zero).	487 sq ft
4. Sail area centroid.	Fuselage station 367.5, water line 28.6
5. Rotor blade clearance;	
a. Ground to tip (forward rotor static).	7 ft, 6.7 in.
b. Ground to tip (rotors turning).	11 ft, 0.9 in.
c. Leading edge of aft pylon to forward rotor blade tip (rotor blade static).	16.7 in.
d. Leading edge of aft pylon to forward rotor blade tip (rotor turning).	40 in.
e. Elevation of aft rotor over forward rotor (at hub).	4 in.
6. Rotor data:	
a. Rotor rpm (normal and military power).	225 to 250
b. Rotor rpm (maximum, autorotation).	261

c. Power loading at alternate design grwt (46,000/5920).	7.76 lb/hp
d. Tip speed, normal at 245 rpm.	768 fps
e. Blade droop stop angle:	
(1) Aft.	3.25 deg
(2) Forward.	4.75 deg
f. Blade coning, stop angle.	30 deg
g. Blade twist, centerline of rotor to tip.	9 deg, 14 sec
h. Rotor diameter.	60.0 ft
i. Number of blades, each rotor.	3
j. Projected disc loading (based on 39,000 lb).	6.90 lb/ft^2
k. Airfoil section designation and thickness.	Modified AMES droop snoot - t/c = 0.10
l. Aerodynamic chord, root and tip.	25.25 in.
m. Width, rotor blades turning.	60.0 ft
n. Length:	
(1) Maximum, rotor blades turning.	98.9 ft
(2) Maximum, rotor blades folded.	51.0 ft
o. Full control travel:	
(1) Longitudinal cyclic	±6.5 in.
(2) Lateral cyclic	±4.18 in.
(3) Directional pedal	±3.60 in.
(4) Thrust control rod	9.12 in.

APPENDIX VI. PHOTOGRAPHS

Photo 1. Right Front View of Helicopter Used During APE III & IV Stability and Control Tests (B-379)

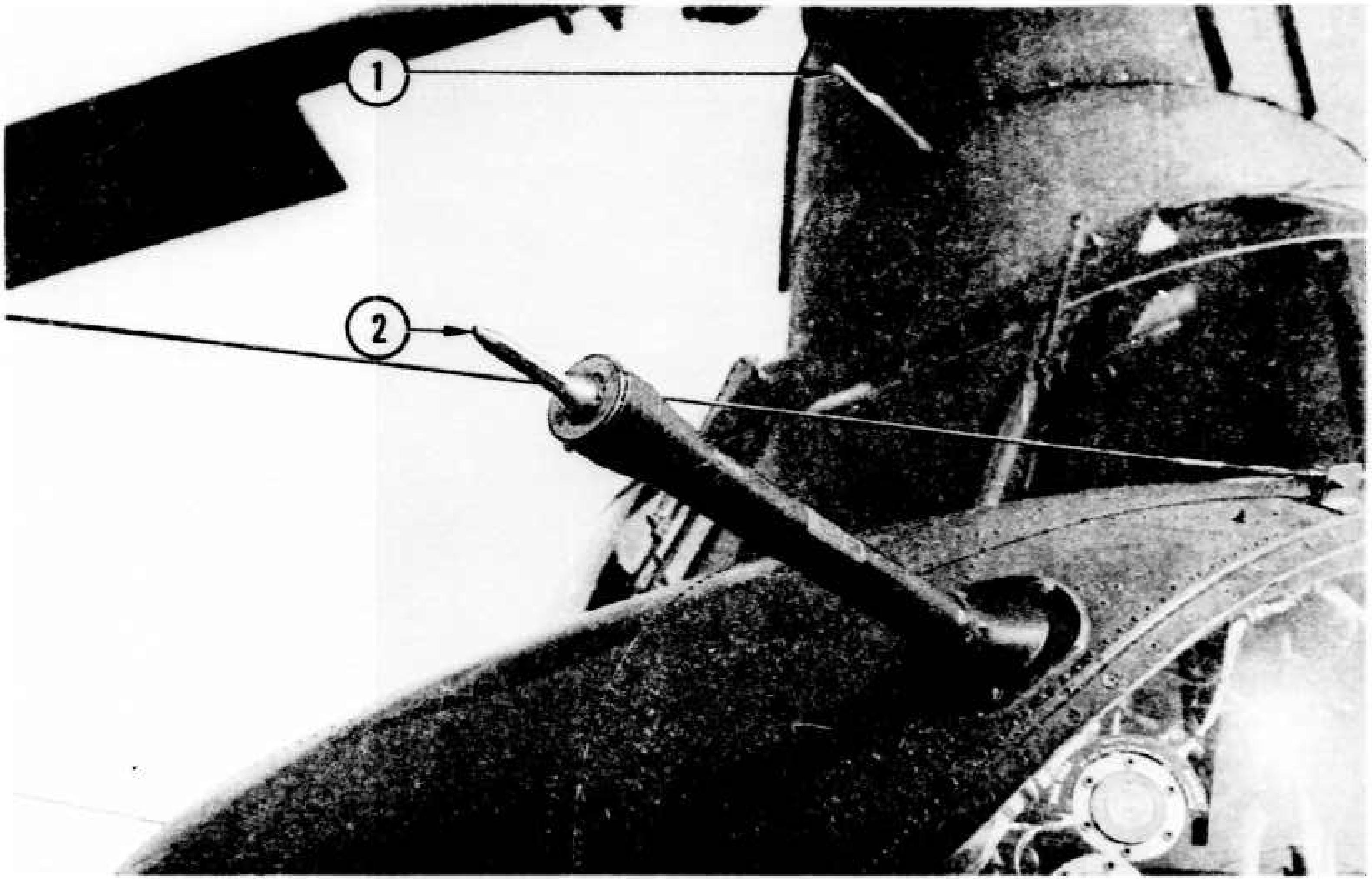


Photo 2. Pitot Probe Mounting On Nose of Helicopter (B-379):
(1) Standard location prior to installation of PSA system
(2) Location for incorporation of PSA system (ECP-611R1)

Photo 3. Left Side View of Helicopter Used During APE 111 Vibration and Noise-Level Tests (B-524)

Photo 4. Right Front View of Helicopter Used During APE IV Vibration Tests (B-570)

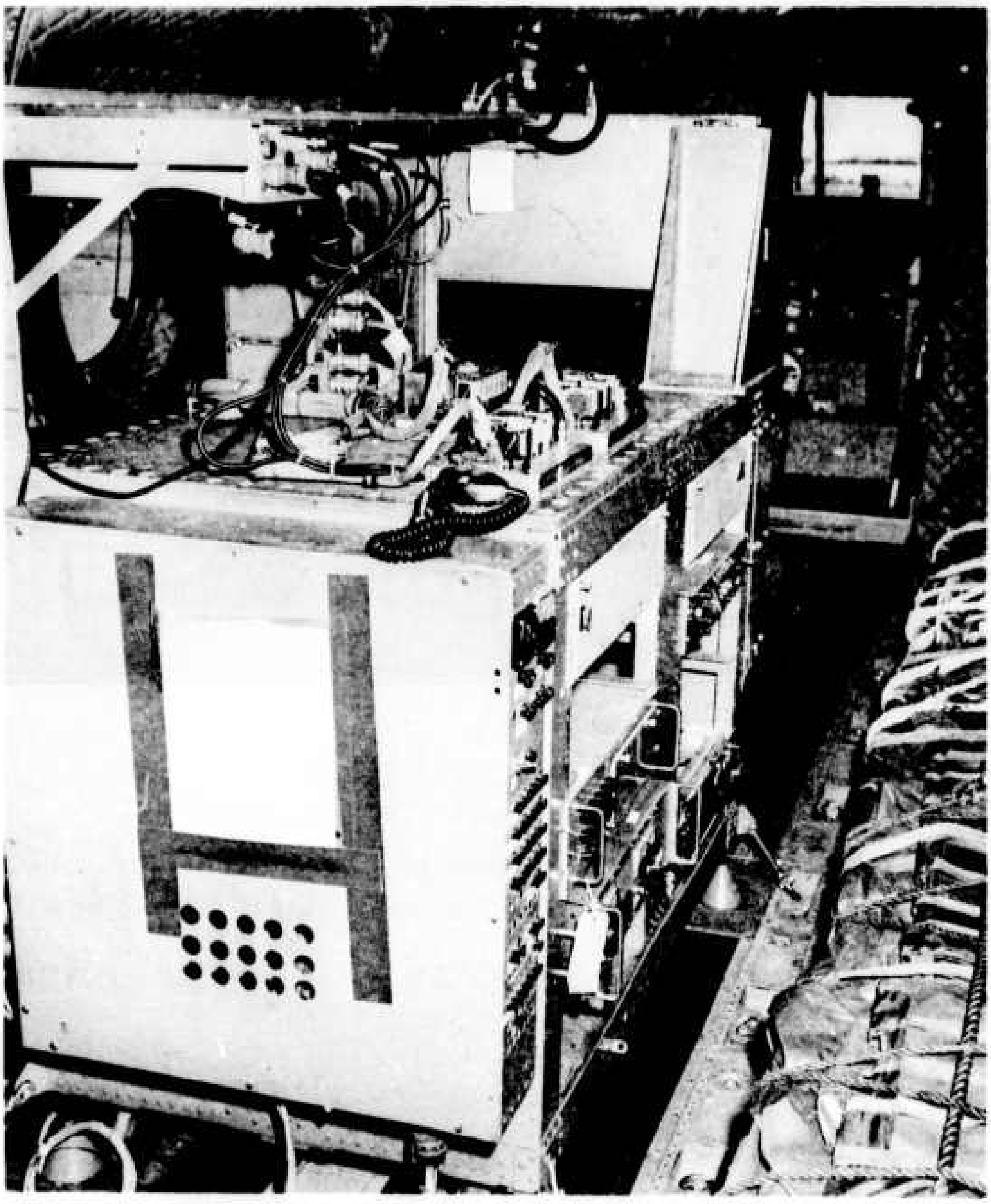


Photo 5. Central Instrumentation Table.
Note: Ballast in Seats, Simulating Troop Loading (B-524)

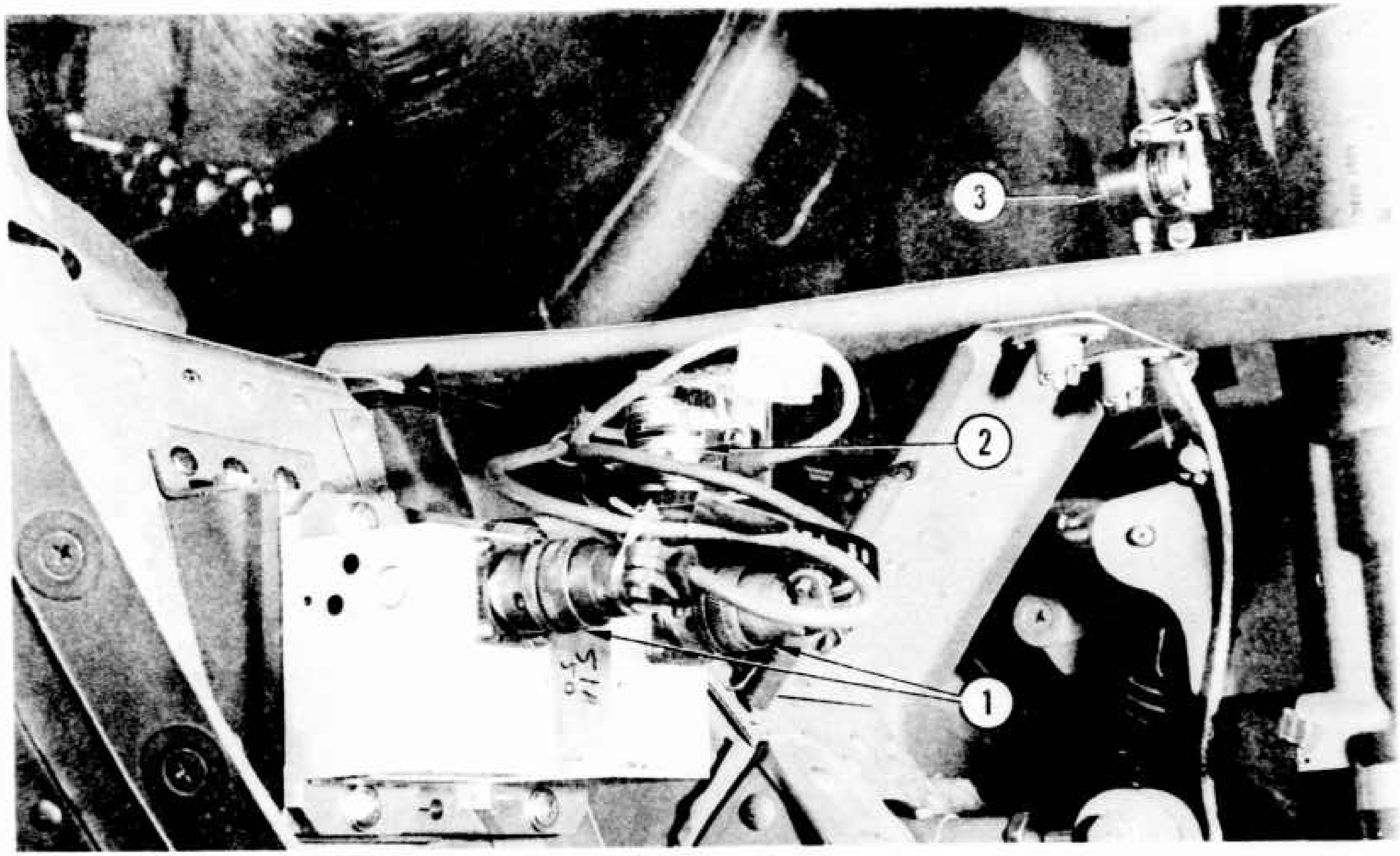


Photo 6. Accelerometer Pickups at:
(1) FS 50 Right
(2) Pilot's Heelslide
(3) Pilot's Directional Pedal

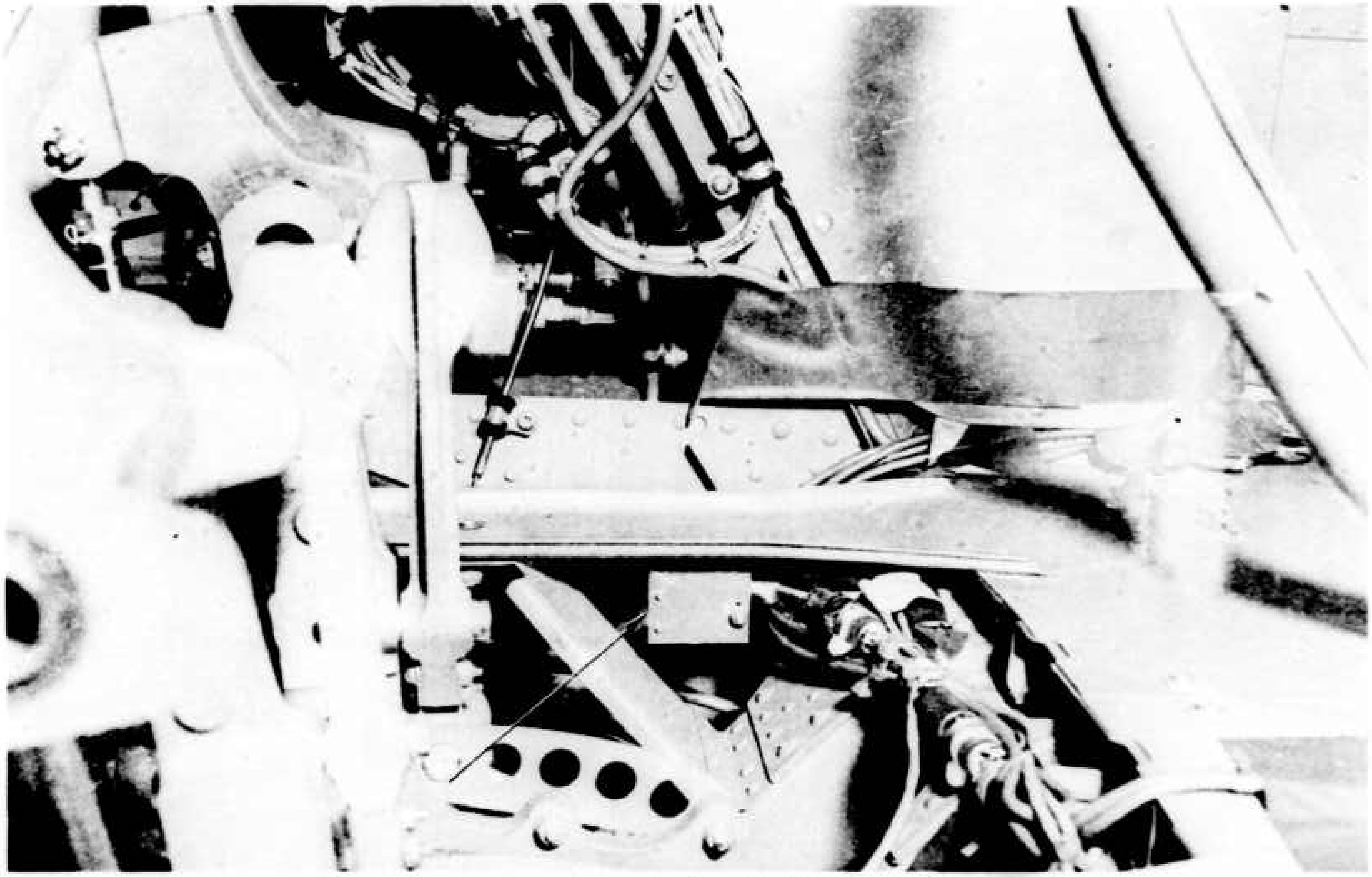


Photo 7. Copilot's Heelslide Vertical Accelerometer Installation

Photo 8. Vertical Accelerometer Installation FS 50 Left

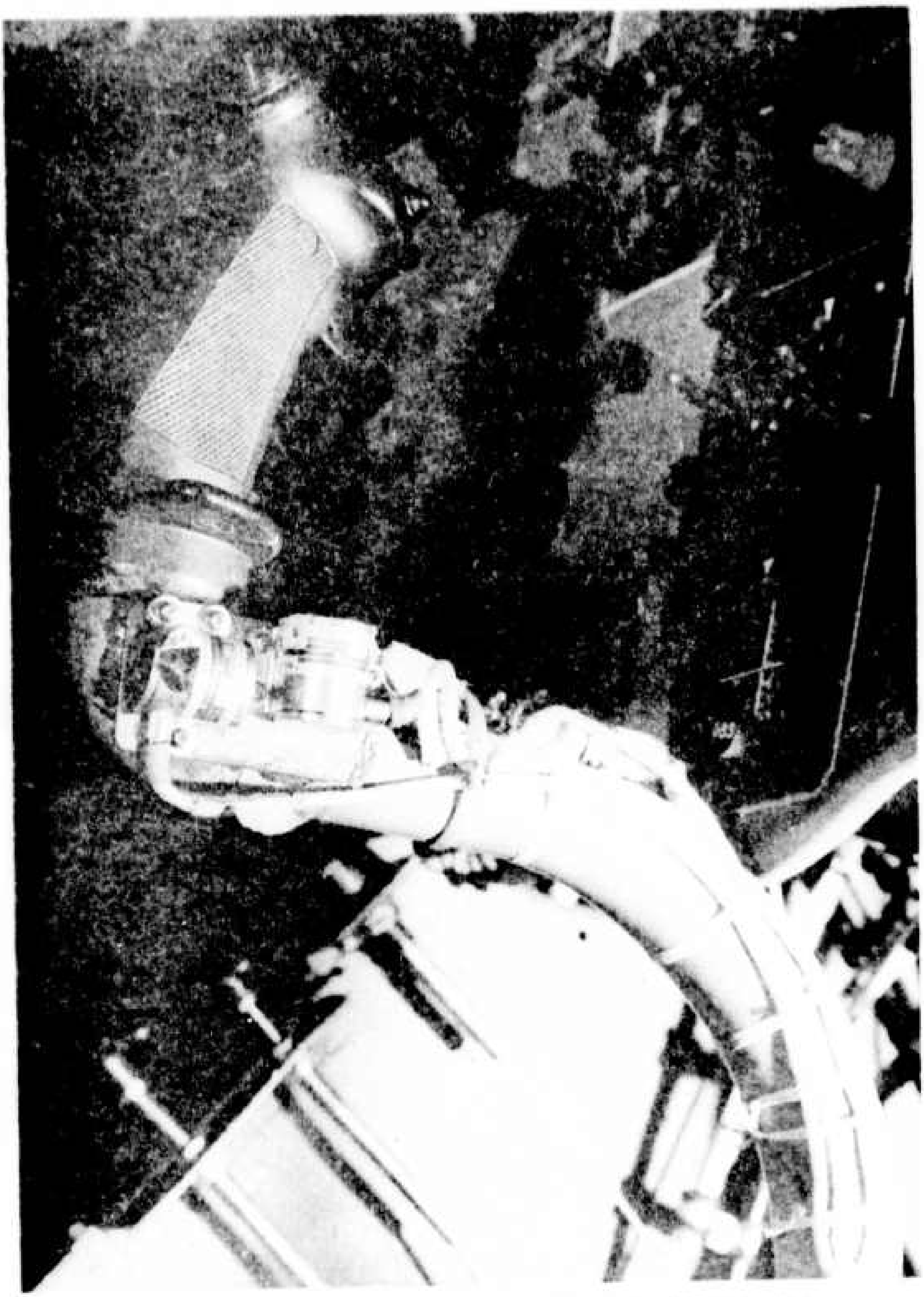


Photo 9. Vertical and Longitudinal Accelerometer Installation - Pilot's Cyclic

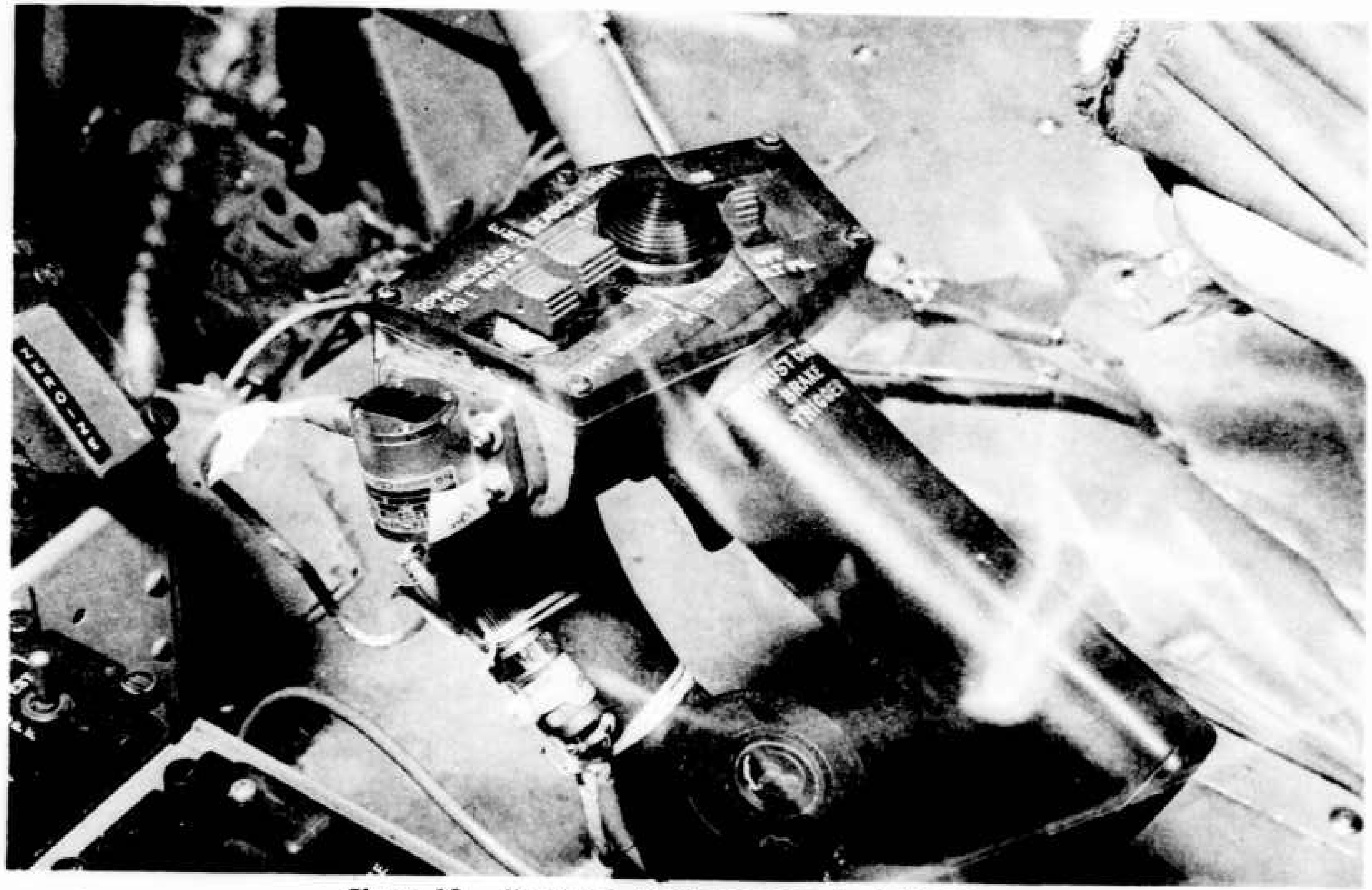


Photo 10. Vertical Accelerometer Installation - Pilot's Thrust Control Rod

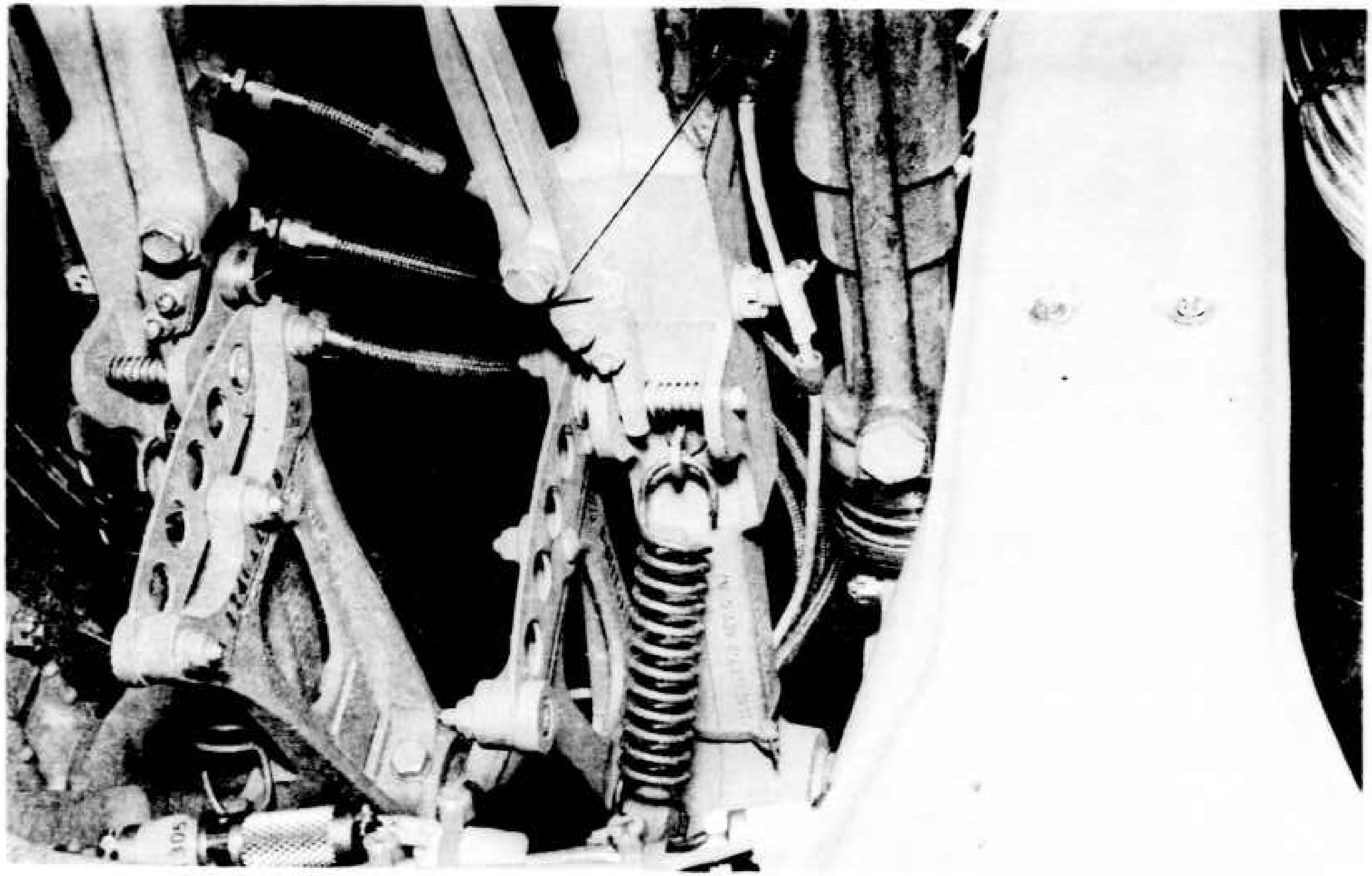


Photo 11. Longitudinal Accelerometer Installation - Pilot's Direction Pedal

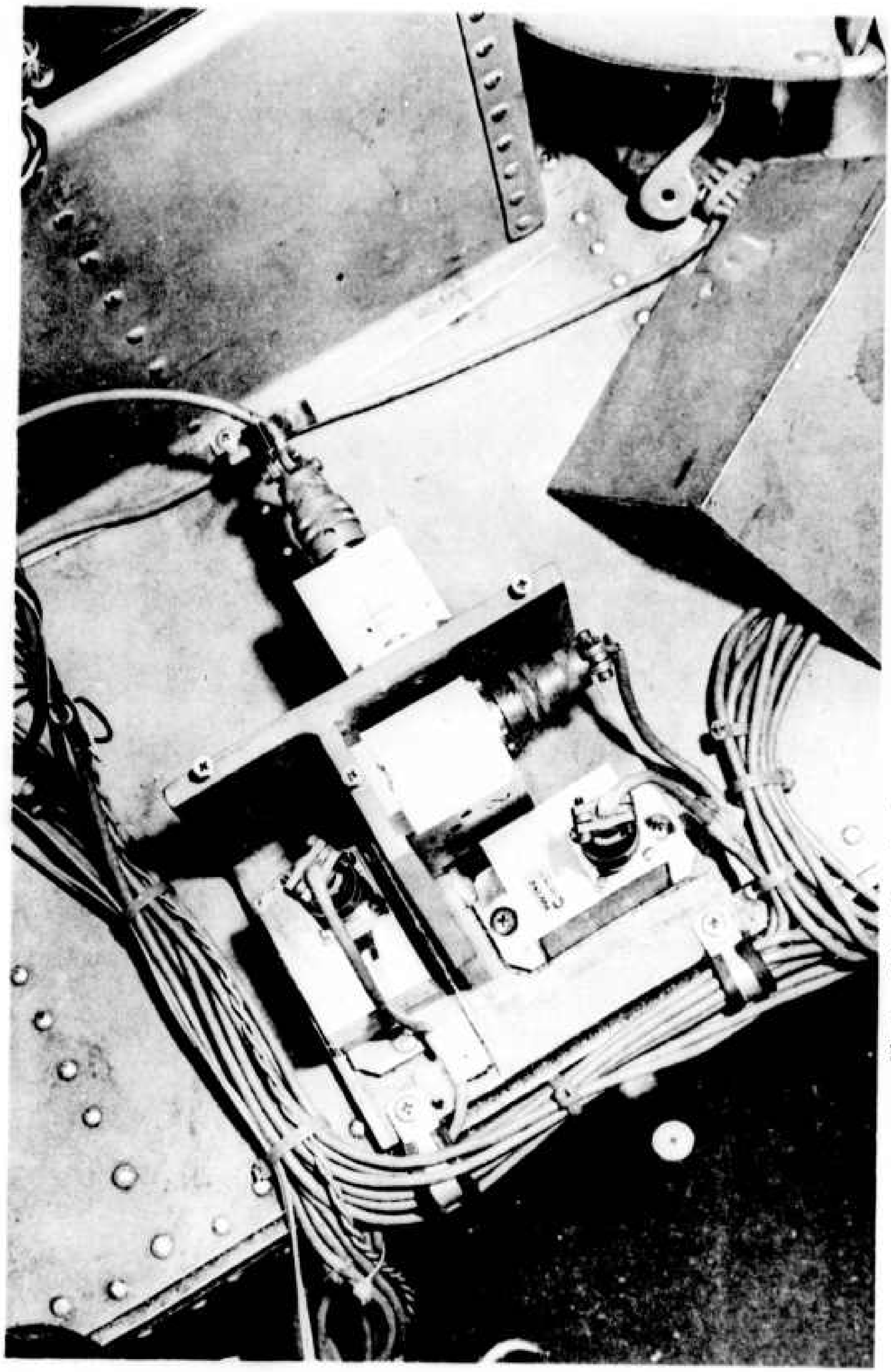


Photo 12. Vertical, Longitudinal and Lateral Accelerometer Installation - FS 95 Center

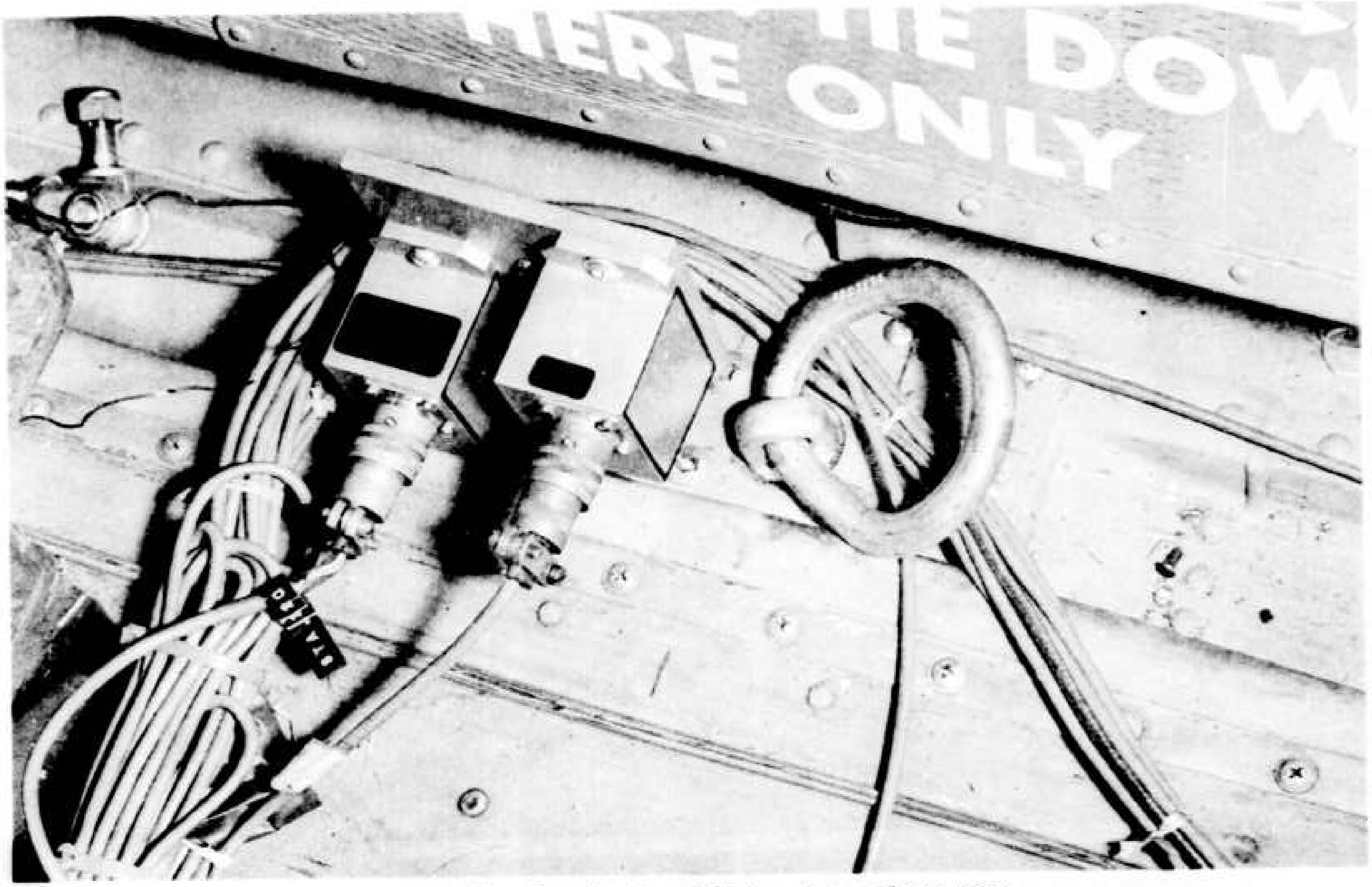


Photo 13. Vertical and Lateral Accelerometer Installation - FS 320 Left, BL 44

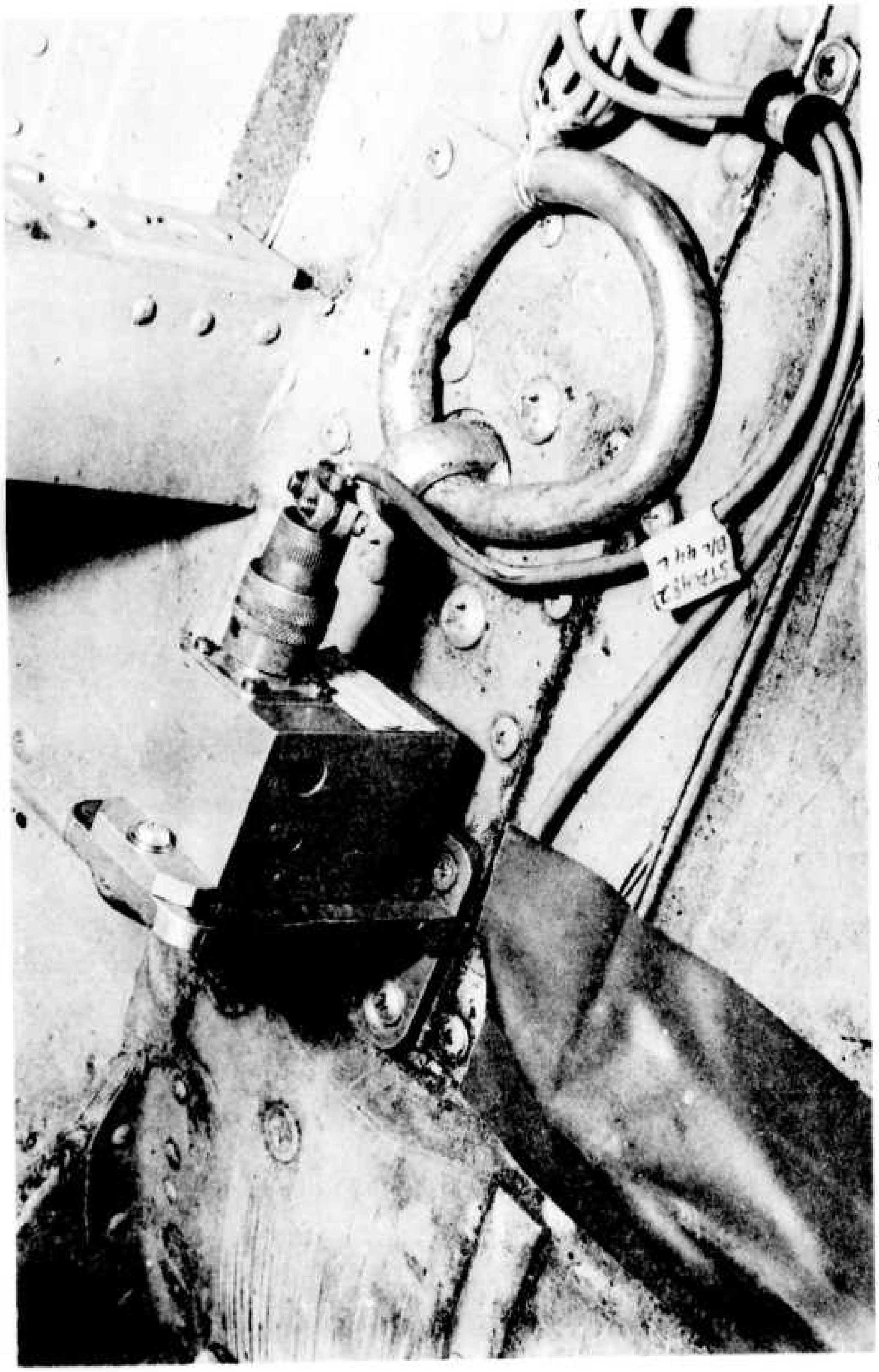


Photo 14. Vertical Accelerometer Installation - FS 482 Left, BL 44 (Used for check only)

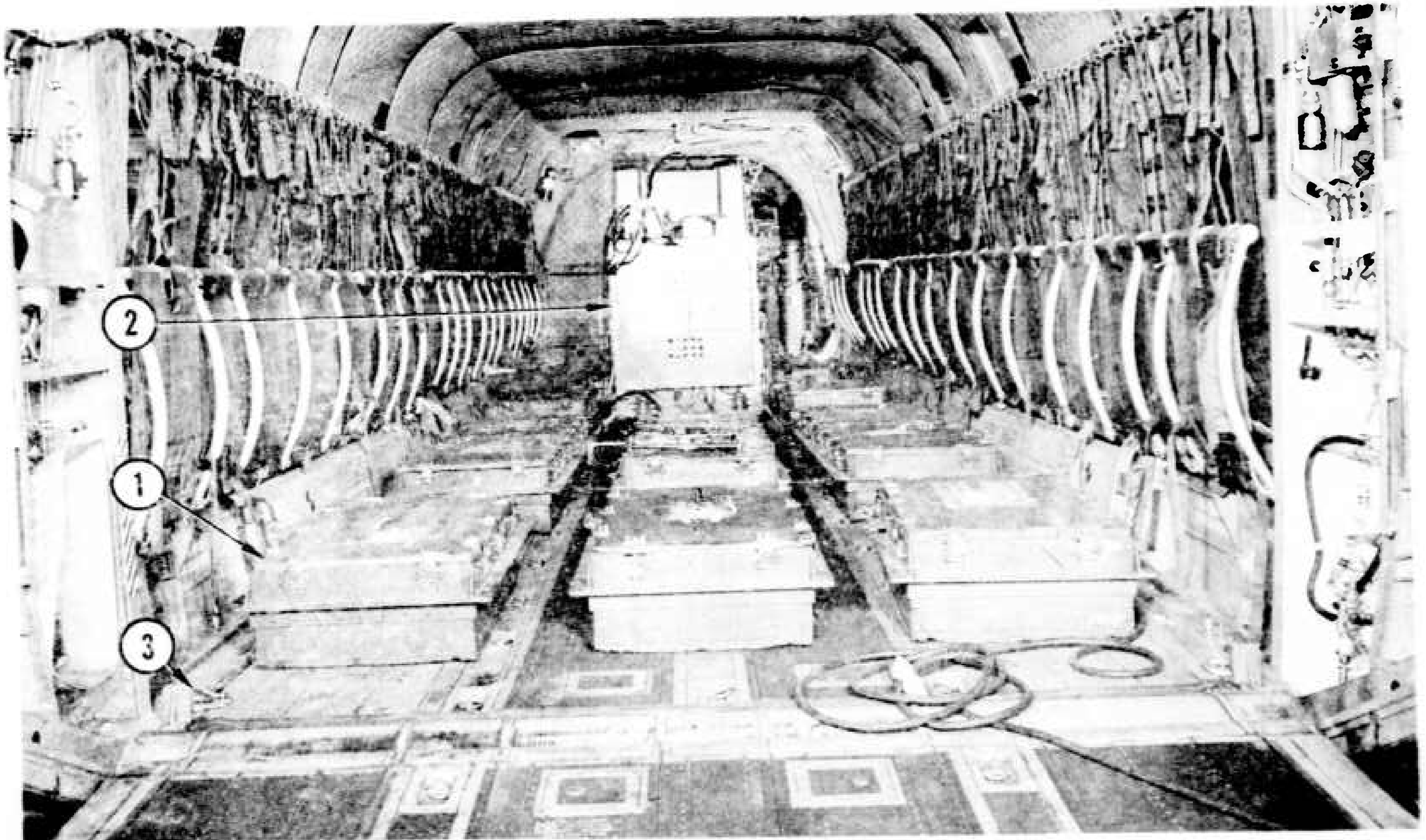


Table 15. Ballast Box Installation During Vibration Tests at Alternate Design Gross Weight of 46,000 Pounds (B-570): (1) Ballast Box
(2) Central Instrumentation Table
(3) FS 482 Vibration Pickups

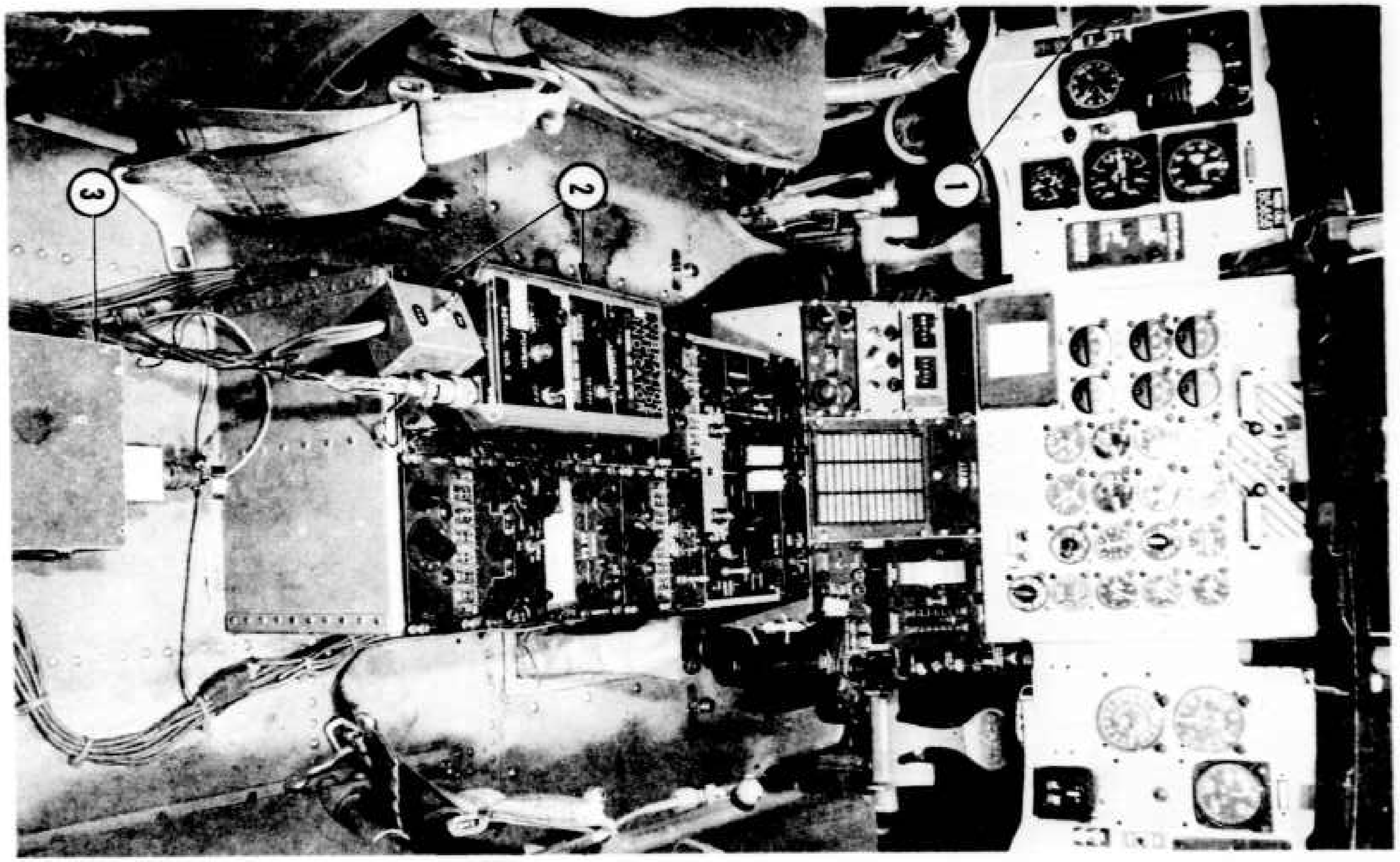


Photo 16. VADI Cockpit Installation (B-570):
(1) Vibration Amplitude Indicator Dial
(2) VADI Control Box
(3) FS 95 Accelerometer Installation

APPENDIX VII. CH-47C FLIGHT TEST ENVELOPES FOR APE III AND IV

Operating Weights

Maximum takeoff weight (for test purposes only)	47,500 lb
Maximum landing weight (for test purposes only)	47,500 lb

Gross Weight - Longitudinal CG Envelope

Gross Weight (lb)	CG Range (in.)
20,000 to 28,500	30.0 fwd to 18.0 aft
33,000	21.3 fwd to 7.0 aft
44,800	12.0 fwd to 5.0 aft
46,000	11.0 fwd to 4.0 aft

Load Factor - Gross Weight Envelope

Gross Weight (lb)	Load Factor (N_z)
20,000 to 35,000	2.0
35,000 to 46,000	2.0 to 1.5

Airspeed - Altitude - Gross Weight

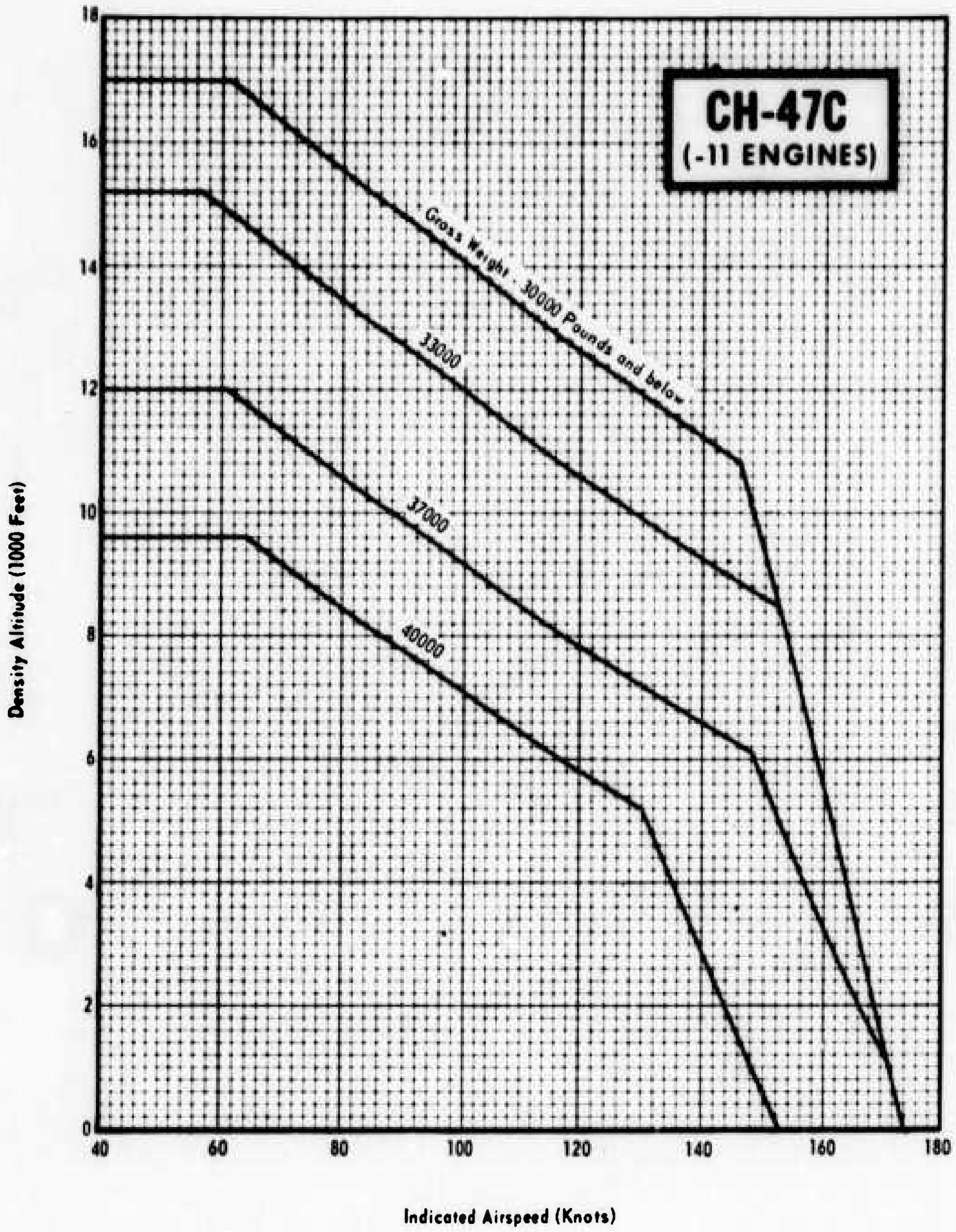
Envelope: 235 to 244 rpm rotor speed (fig. A)

Airspeed - Altitude - Gross Weight

Envelope: 245 to 247 rpm rotor speed (fig. B)

Airspeed - Sideslip Envelope

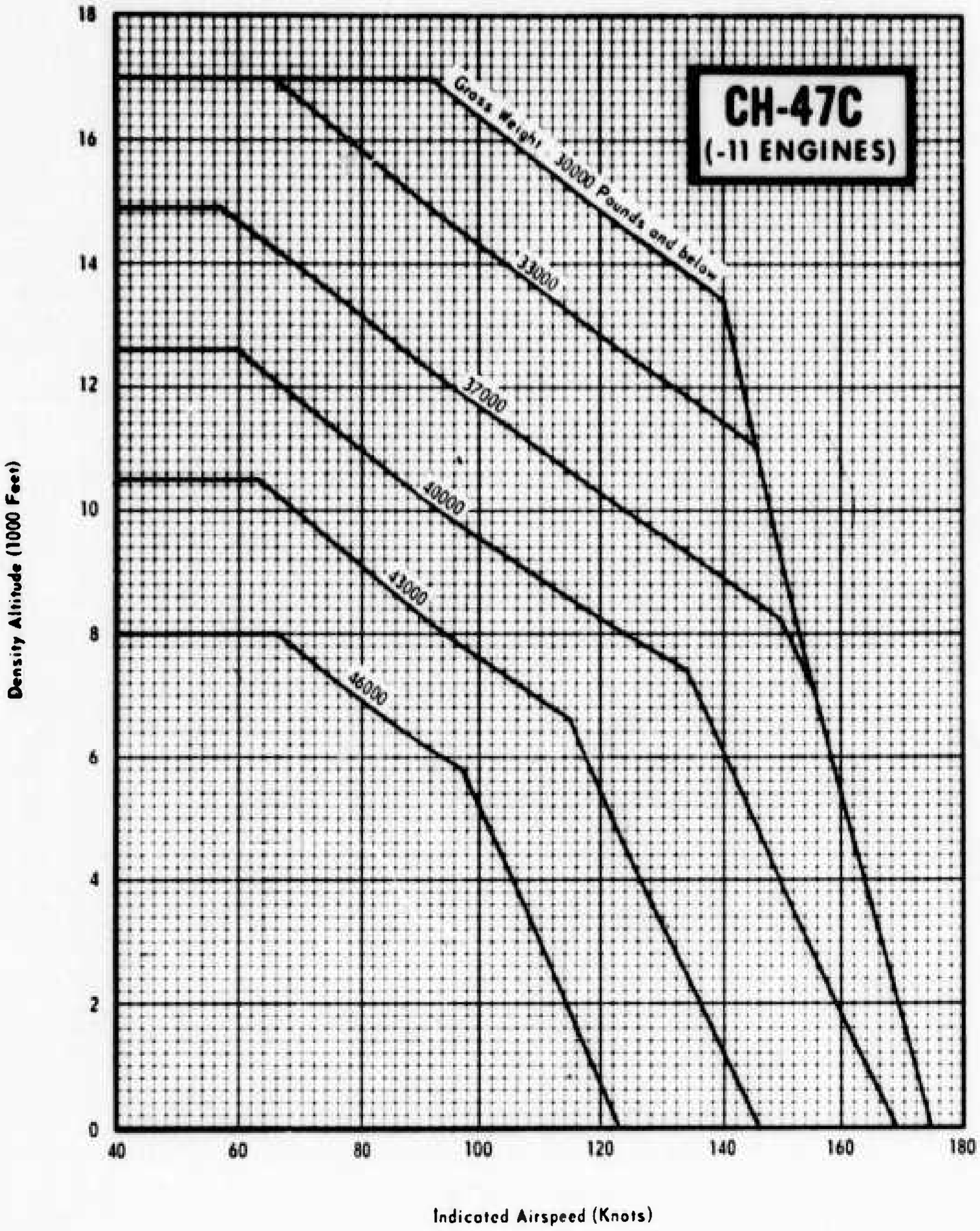
Airspeed (KTAS)	Sideslip Angle (deg)
0 to 36	90
37	47
170	15



NOTES:

1. Use PROGRAMED longitudinal cyclic speed trim.
2. Use 235 rotor rpm.
3. Observe center-of-gravity limits.
4. When density altitudes are below sea level, observe sea level airspeed limits.

Figure A. Airspeed Limitations - 235 rotor rpm.



NOTES:

1. **Use PROGRAMED longitudinal cyclic speed trim.**
2. **Use 245 rotor rpm.**
3. **Observe center-of-gravity limits.**
4. **When density altitudes are below sea level, observe sea level airspeed limits.**

Figure B. Airspeed Limitations - 245 rotor rpm.

Airspeed - Bank Angle Envelope

Gross Weight (lb)	Airspeed (kt)	Bank Angle (deg)
46,000 and below	V_{NE}	35
	V_{NE}-10 and below	45

Rotor Speed Limitations

Power on (hover)	223 to 250 rpm
Power on (except hover)	223 to 242 rpm
Power off	223 to 261 rpm

YT55-L-11 Engine Operating Limitations

Ratings	SHP	Output Shaft Speed (rpm)	Measured Gas Temperature T.I.T. (°C)
Maximum (10 min)	3750	16,000	896
Military (30 min)	3400	16,000	849
Normal	3000	15,950	804

N_1 per engine run sheets.

Measured gas temperatures during starting and acceleration are 940° and 910°C, respectively.

Maximum torque is 1300 ft-lb.

Engine Oil Data

	Pressure (psi)	Temperature (°F)
Normal rated power	70 ±20	190
GI	20(min)	190

Note: Transmission ratio equals output shaft speed/rotor speed: 16,000/250 equals 64:1

APPENDIX VIII. GLOSSARY OF TERMS

SYMBOL	DEFINITION	UNIT
BL	Butt line	
g	Normal acceleration	g_o or G Gravitational constant
LH	Left hand	
N	Rotor speed	Revolutions per minute
$N/\sqrt{\theta}$	Referred rotor speed	
θ	Ratio of ambient temperature to standard temperature at sea level	
δ	Ratio of ambient pressure to standard pressure at sea level	
RH	Right Hand	
$SHP/\delta\sqrt{\theta}$	Generalized shaft horsepower	
V	Airspeed	
$V/\sqrt{\theta}$	Referred Airspeed	
W	Weight	
W_f	Fuel Flow	
$W_f/\delta\sqrt{\theta}$	Referred fuel flow	
WL	Water line	

APPENDIX IX. PILOT RATING SCALE

CONTROLLABLE CAPABLE OF BEING CONTROLLED OR MANAGED IN CONTEXT OF MISSION, WITH AVAILABLE PILGT ATTENTION	ACCEPTABLE MAY HAVE DEFICIENCIES WHICH WARRANT IMPROVEMENT, BUT ADEQUATE FOR MISSION. PILOT COMPENSATION, IF REQUIRED TO ACHIEVE ACCEPTABLE PERFORMANCE, IS FEASIBLE.	SATISFACTORY MEETS ALL REQUIREMENTS AND EXPECTATIONS, GOOD ENOUGH WITHOUT IMPROVEMENT CLEARLY ADEQUATE FOR MISSION.	EXCELLENT, HIGHLY DESIRABLE	A1
			GOOD, PLEASANT, WELL BEHAVED	A2
			FAIR. SOME MILDLY UNPLEASANT CHARACTERISTICS. GOOD ENOUGH FOR MISSION WITHOUT IMPROVEMENT.	A3
		UNSATISFACTORY RELUCTANTLY ACCEPTABLE. DEFICIENCIES WHICH WARRANT IMPROVEMENT. PERFORMANCE ADEQUATE FOR MISSION WITH FEASIBLE PILOT COMPENSATION.	SOME MINOR BUT ANNOYING DEFICIENCIES. IMPROVEMENT IS REQUESTED. EFFECT ON PERFORMANCE IS EASILY COMPENSATED FOR BY PILOT.	A4
			MODERATELY OBJECTIONABLE DEFICIENCIES. IMPROVEMENT IS NEEDED. REASONABLE PERFORMANCE REQUIRES CONSIDERABLE PILOT COMPENSATION.	A5
			VERY OBJECTIONABLE DEFICIENCIES. MAJOR IMPROVEMENTS ARE NEEDED. REQUIRES BEST AVAILABLE PILOT COMPENSATION TO ACHIEVE ACCEPTABLE PERFORMANCE.	A6
	UNACCEPTABLE DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT. INADEQUATE PERFORMANCE FOR MISSION EVEN WITH MAXIMUM FEASIBLE PILOT COMPENSATION.		MAJOR DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT FOR ACCEPTANCE. CONTROLLABLE. PERFORMANCE INADEQUATE FOR MISSION, OR PILOT COMPENSATION REQUIRED FOR MINIMUM ACCEPTABLE PERFORMANCE IN MISSION IS TOO HIGH.	U7
			CONTROLLABLE WITH DIFFICULTY. REQUIRES SUBSTANTIAL PILOT SKILL AND ATTENTION TO RETAIN CONTROL AND CONTINUE MISSION.	U8
			MARGINALLY CONTROLLABLE IN MISSION. REQUIRES MAXIMUM AVAILABLE PILOT SKILL AND ATTENTION TO RETAIN CONTROL.	U9
UNCONTROLLABLE CONTROL WILL BE LOST DURING SOME PORTION OF MISSION.			UNCONTROLLABLE IN MISSION.	10

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13. ABSTRACT

Army Preliminary Evaluation (APE) III and IV of the CH-47C helicopter was conducted in the vicinity of Philadelphia, Pennsylvania. APE III consisted of vibration noise level tests and a re-evaluation of the stability and control characteristics modified by the incorporation of engineering changes to correct the handling qualities deficiencies found during APE II. APE IV was a re-evaluation of the vibration characteristics which was required because of structural modifications incorporated in the aircraft following APE III. The helicopter showed significant improvements in trimmability, static and dynamic longitudinal stability and lateral-directional stability as compared to aircraft flown during APE I and II. The longitudinal stability improvements permitted sustained "hands off" flight. The vibration levels experienced during APE IV were improved over APE III. The aircraft met all requirements except two of the detail specification and two of the military specification. No deficiencies were detected; however, correction of 16 shortcomings is desirable for improved helicopter operation. The primary shortcomings detected during these tests are uncommanded pitch attitude changes while retrimming in the pitch stability augmentation (PSA) system ON/detent OFF mode and high noise levels in the cockpit and cabin areas. Other shortcomings are: unstable and neutral longitudinal trim position gradients, uncommanded pitch attitude changes following failure of the PSA system airspeed and attitude feedback signals, blade "bang" (rotor blade noise) phenomenon, uncommanded auxiliary power unit shutdown and inaccurate fuel quantity indications. The high, thrust control rod sensitivity, pitch-to-thrust aerodynamic coupling and basic stability augmentation system static and dynamic longitudinal instability shortcomings reported in APE II are still present.

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CH-47C Helicopter						
Vibration Testing						
Re-evaluation of handling qualities						